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ABSTRACT

This conference presented a discussion of problems related to federal budgeting for research and development (R&D). It was organized around three working sessions. The first session considered the 1977 budget for R&D and the future outlook for R&D. The second session was devoted to the Congressional role in R&D budgeting. The third session addressed some of the fundamental problems of the budgeting process as it affects R&D. (BB)

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AAAS Committee on Science and Public Policy

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Research & Development in the Federal Budget

Colloquium Proceedings
June 15-16, 1977

Edited by
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Introduction

The 15-16 June 1977 Colloquium on Research and Development in the Federal Budget was the second in what AAAS hopes will be a continuing series of mid-year colloquia on current science policy issues. The colloquium brought together leaders of the scientific and technological communities with responsible decision-makers in the Executive and Legislative branches of government to discuss problems of R&D budgets and the budget process as it affects R&D. The purpose of the colloquium was not so much to debate the budget numbers for R&D, but to use the budget as a departure point for considering basic questions in R&D policy. As Emilio Q. Daddario, AAAS President, stated in his welcoming remarks, "Our real purpose . . .[is] to see the budget as a window upon the policy-making process as it affects science and technology, and as it recognizes--or fails to recognize--the uses of science in reaching goals and objectives."

Almost 250 participants from government, industry, academia, and the media attended the colloquium, which consisted of three panel discussion sessions and five major addresses. The AAAS report Research and Development in the Federal Budget: FY 1978* provided the starting point for the presentations and discussion in each of the panel sessions: "R&D Budgets and Future Outlook"; "Congressional Role in R&D Budgeting"; and "How Should R&D Decisions Be Made?" The addresses by distinguished representatives from the Executive Office of the President, the Department of Commerce, Congress, and indusry raised additional issues for consideration by the group. W. Bowman Cutter, Office of Management and Budget, provided an up-to-date report on the status of R&D in the deliberations in the Carter Administration on the FY 1979 budget; William Nordhaus, a member of the Council of Economic Advisers, discussed the role of research in economic growth; Robert Hirsch, EXXON Corporation, analyzed the non-technical problems of energy R&D; Senator Adlai Stevenson presented a Congressional

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* This report, as well as Research and Development in the Federal Budget: FY 1977 and the proceedings of the 1976 colloquium can be obtained from AAAS.

perspective on R&D; and Jordan Baruch, Assistant Secretary of Commerce, in the final session of the colloquium, left the participants to ponder the application of "infratechnology" to problems where traditional research and development processes do not provide solutions.

A day-and-a-half colloquium cannot expect to arrive at answers to the complex questions surrounding our country's R&D policies. We believe, however, that real progress has been made toward creating a means through which the federal government and the scientific community can better understand each other's perspectives on R&D issues and toward stimulating more effective participation by the scientific community in the R&D budget process. Based on the positive responses to the first two colloquia, we plan to broaden the scope of future colloquia to include areas in addition to federal R&D budgeting in which science policy considerations play a major role.

The AAAS reports and colloquia on R&D in the federal budget have been conducted with the guidance of the AAAS Committee on Science and Public Policy, and oversight by the AAAS Board of Directors. Advice has also been provided by representatives of scientific and engineering societies affiliated with AAAS, and we are exploring ways for expanding cooperative efforts with these organizations in AAAS R&D budget and other science and public policy activities.

September
1977

William D. Carey
Executive Officer
AAAS

Agenda for the Colloquium

Wednesday, 15 June

10:00 am **Welcome:** Emilio Q. Daddario, *President, AAAS*

Introduction: J. Thomas Ratchford, *Associate Executive Officer, AAAS*

Conference Overview: Willis H. Shapley, *Consultant to the AAAS for the R&D Budget Analysis*

Opening Addresses: W. Bowman Cutter, *Executive Associate Director for Budget, Office of Management and Budget*

William Nordhaus, *Member, Council of Economic Advisers*

12:30 pm **Lunch**

Presiding: John M. Logsdon, *Director, Graduate Program in Science, Technology and Public Policy, George Washington University, and Chairman, AAAS Committee on Science and Public Policy*

Address: Robert Hirsch, *Deputy Manager for Science and Technology, EXXON Corporation*

2:30 pm **R&D Budgets and Future Outlook**

Moderator: William D. McElroy, *Chancellor, University of California, San Diego, and Chairman, AAAS Board of Directors*

Panelists: John Stewart, *Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate*

Hugh F. Loweth, *Deputy Associate Director, Science and Energy Technology, Office of Management and Budget*

Philip M. Smith, *Assistant Director for Natural Resources and Commercial Services, Office of Science and Technology Policy*

Merwyn C. Greer, *Controller, Energy Research and Development Administration*

Robert L. Stern, *Director, Business/Government Relations Research, The Conference Board*

T. Dixon Long, *Provost, Western Reserve College, Case Western Reserve University, and Member, AAAS Committee on Science and Public Policy*

5:30 pm **Reception and Buffet Dinner**

Presiding: The Honorable Mike McCormack, *U.S. House of Representatives, and Member, AAAS Board of Directors*

Address: The Honorable Adlai E. Stevenson, *United States Senate*

7:30 pm **Congressional Role in R&D Budgeting**

Moderator: The Honorable Ray Thornton, *U.S. House of Representatives*

Panelists: Hunter L. Spillan, *Committee on Appropriations, U.S. House of Representatives*

Robert B. Clark, *Committee on Appropriations, United States Senate*

Sanford A. Lakoff, *Professor of Political Science, University of California, San Diego, and Member, AAAS Committee on Science and Public Policy*

N. Richard Werthamer, *Chairman, New York State Energy Research and Development Authority*

Herbert Roback, *Director of Studies for the Commission on Federal Paperwork, and Author of Section on "Congress and R&D Budgeting" in Research and Development in the Federal Budget: FY 1978*

Thursday, 16 June

10:00 am **How Should R&D Decisions Be Made?**

Moderator: Ruth M. Davis, *Deputy Undersecretary of Defense Designate for Research and Advanced Technology, and Member, AAAS Board of Directors*

Panelists: Philip B. Yeager, *Committee on Science and Technology, U.S. House of Representatives*

Alvin L. Alm, *Energy Policy and Planning Office, Executive Office of the President*

Willis H. Shapley, *Consultant to the AAAS for the R&D Budget Analysis*

Eliot R. Cutler, *Associate Director for Natural Resources, Energy, and Science, Office of Management and Budget*

John C. Calhoun, Jr., *Vice-President for Academic Affairs, Texas A&M University*

1:00 pm **Lunch**

Presiding: William D. Carey, *Executive Officer, AAAS*

Address: Jordan Baruch, *Assistant Secretary for Science and Technology, Department of Commerce*

Concluding Remarks: William D. Carey

Welcome

Emilio Q. Daddario
President, AAAS

I welcome you to the second annual AAAS Colloquium on Research and Development in the Federal Budget.

In the past decade, the fortunes of R&D have been decidedly mixed. Like the national economy itself, they have maintained fast growth followed by slump and then slow recovery. The scale of federally supported R&D has increased substantially, measured by inflationary dollars, but in terms of constant dollars the movement has been more modest. Because the federal funding role exerts such strong leverage on the mix and priorities of research and development, the health and productivity of research is dependent on the quality and stability of government policy.

This colloquium is not a rally to whip up support for larger R&D budgets. Although nobody is certain as to "how much is enough" for R&D, either in the public or the private sector, it is important for us to have a better understanding of and confidence in the policymaking system which produces outcomes -- substantive as well as budgetary.

A year ago, AAAS attempted its first systematic examination of the treatment of R&D in the federal budgeting process. We weren't sure that we could get our hands on it. As things turned out, thanks to Willis Shapley and our Committee on Science and Public Policy, we came out with a report which is generally regarded as a landmark in science policy research. I've talked to certain people in the present Administration who have told me that the report has been of great help to them. We held the initial colloquium, and it was a lively one.

Now we have a second report, which examines the President's budget in R&D terms for FY 1978. There is more analysis of the decisions, and less basic explanation as to how the budget-making process is initiated and developed. There is more attention in the new report to the Congressional role in budgeting for R&D, and perhaps the highlight of this year's report is the extremely imaginative chapter by Willis Shapley on new and better ways for allocating federal resources to R&D.

But it's important to remember that budgets come and budgets go, and that they will always reflect the attitudes and constraints felt by the President and the Congress. Our real purpose in these studies and colloquia isn't so much to debate the wisdom of the numbers, but rather to see the budget as a

window upon the policymaking process as it affects science and technology, and as it recognizes -- or fails to recognize -- the uses of science in reaching goals and objectives. The budget is a departure point for science policy research.

Over these two days we will be hearing from many distinguished representatives from the Executive Branch, the Congress, private industry, and universities. We expect vigorous participation from all of you. As President of AAAS, I want to thank Chairman John Logsdon and all the members of the Committee on Science and Public Policy for their efforts and the Sloan Foundation for its generous support, and agin to welcome all of you as I return the podium to Dr. Ratchford.

Conference Overview

Willis H. Shapley
Consultant, AAAS Committee
on Science & Public Policy

I will take just a few minutes to give a brief overview of what is planned and what we hope will happen at this, the second AAAS colloquium on research and development in the federal budget.

The basic aim, as you know, is a useful discussion of problems related to federal budgeting for R&D, in which people from various parts of the national scientific and technical community can exchange views with responsible officials of the government from the Executive and Legislative Branches. We will be privileged to hear from several distinguished speakers as indicated in your programs, with the first two -- Mr. Cutter and Dr. Nordhaus -- leading off in a few moments. All of these speakers hold responsible positions in the Executive Branch, Congress, or industry; they will address a variety of topics related to R&D budgeting and R&D policy, and, I am sure, will be glad to answer questions after their talks to the extent feasible.

We will also be meeting in three working sessions. This year, our report and the working sessions have been structured around the three topics indicated in the agenda which I will say a little more about in a moment. These topics are broad enough to cover just about the entire range of problems of R&D budgets, the budget process, and national policy on R&D. Our hope, however, is that without artificially restricting the scope of the discussion we will be able to focus on the principal issues of current importance, arrive at some common understanding, and try to achieve a consensus on how they should be dealt with.

The first working session, this afternoon, will consider the current budgets for R&D and the future outlook for R&D. Chapters 3 and 4 of the report provide a starting point and suggest the following as among the most important questions to be addressed:

1. What are the major substantive issues in the R&D budgets for FY 1978 now being acted on by Congress?

2. What general policies should govern the preparation of R&D budgets for FY 1979? What changes should or are likely to be made in the policies followed by President Ford in his FY 1978 budget? (These policies are summarized on pages 14-17 of the AAAS report.)

3. What is and what should be the outlook for federal R&D budgets for the next five years? Is continued annual "growth" needed? Is it likely? In what areas? (Chapter 4 of the report gives some illustrative projections based on alternative assumptions.)

4. What are the implications of probable future budget trends? What would be the impact of higher or lower R&D budgets? What are the implications for meeting national needs? For the economy? For scientific and technical progress? For international cooperation and competition? For R&D institutions and the R&D enterprise -- for universities, for R&D in industry, for government agencies and laboratories? This set of questions covers an area where we are especially hopeful that all of you will help provide insights, if not answers, from your own knowledge and perspectives. The implications for universities can be considered in the light of the excellent report, The State of Academic Science by Professors Bruce Smith and Joseph Karlesky and published by Change Magazine Press under a grant from the Sloan Foundation. (An inspection copy is supposed to be available at the registration desk for those interested.)

5. A final important question for the first working session is the outlook for R&D in industry. While industry R&D as such has been outside the scope of our AAAS project as it has been defined up to now, there are many important interactions between industry and federal R&D, and industry R&D is clearly a major component in the nation's R&D efforts. (Some of the pertinent questions are outlined on pages 106-109 of the report, and we hope that both speakers and participants will have something to say about the significance and outlook for R&D in industry.)

The first working session, then is concerned with substantive questions related to R&D budgets. In the other two sessions the focus will be more on the budget and decision processes, although substantive questions of course are not excluded.

The second working session will come this evening, after Senator Stevenson's address at the buffet dinner, and will be devoted to the Congressional role in R&D budgeting, with Congressman Ray Thornton as moderator. Chapter 6 of the AAAS report, written by Herbert Roback, provides a point of departure. Some of the key questions to discuss are:

1. How is the new Congressional budget process working? What effect is it having on R&D budgets?

2. What are the problems of Congressional budget review in R&D? Is it too detailed? Or too broad-brush? How essential is the "double look" by authorization and appropriation committees?

3. A final question on a subject on which it would be good to have expert advice from the panelists: How can the scientific and technical community participate most effectively in Congressional actions on R&D budgets? What are the dos and don'ts for scientists and their organizations in dealing with Congress?

Tomorrow morning, at the third working session, with Ruth Davis as moderator, we will try to zero in on some fundamental problems of the budget process as it affects R&D. The topic will be "How should R&D budget decisions be made?"

This session will provide a forum for the panelists and participants from the floor to exchange views on the policies, rationales, and criteria that should govern R&D budget decisions, and on related problems of the budget process.

While we don't want to restrict the scope unduly, we do want to try to advance the discussion beyond the identification of problems and suggestion of additional points to be taken into account. Last year's AAAS report and colloquium explored the problems in some depth. We learned that every budget issue has at least two sides. We gained an appreciation of the complexities and of the many different standpoints and conflicting considerations that have to be accommodated.

This year we are trying to pull it all together and see if we can arrive at, or at least approach, a consensus on how R&D budget decisions should be made that is acceptable to each of the standpoints involved -- acceptable to the scientific and technical community, to those charged with the management and direction of R&D and to the budgetary authorities in the Executive Branch and Congress.

To guide the discussion in this direction, the report presents -- in the ten pages of Chapter 5 -- a concrete proposal to serve as a strawman or working hypothesis for the panel and colloquium to shoot at. It has two parts, which could be considered one after the other.

First, I have tried to pull together the points developed last year into a coherent concise statement of conditions to be met (and some to be avoided) in the budget decision process for R&D. This listing of conditions attempts to reflect the essential needs of the process as seen from the several different standpoints involved -- agency management, OMB, Congress, the

scientific and technical establishment, and the workings of our system of government.

The idea is for the panelists and participants in the third working session to dissect and debate this list of conditions, change or add to it, and see how close we can come to a consensus on the conditions that really should govern budget decisions.

In the second part of Chapter 5, I have invented, helping myself freely to ideas and experience of others, a "system" for budgeting that might meet the necessary conditions; I've called it "Controlled Commitment Budgeting" (CCB). This is another strawman to shoot at. CCB isn't intended to be a system in quite the same sense as Zero-Base Budgeting or PPBS; it is conceptual rather than procedural in its present form, at least. But it tries to show how R&D budget decisions could be handled in a way that could meet the needs of overall fiscal control of spending levels and program commitments as well as the needs of R&D managers and the people actually doing the work. Again, the idea is for panelists and participants at the third session to critique this proposal and suggest changes and improvements, and see how far we can get toward a consensus.

Let me close by saying that the preparation of the AAAS report has not been a one-man operation. I want to thank Don Phillips and Herbert Roback for their work in helping prepare the year's report, the Committee on Science and Public Policy for its guidance and patience, the Sloan Foundation for its support, and finally, but not least, all of you for your interest and attendance, and -- in advance -- for the contributions I am sure you will make to our colloquium today and tomorrow.

Opening Addresses

W. Bowman Cutter
Executive Associate Director
for Budget
Office of Management and
Budget

W. Bowman Cutter was named Executive Associate Director for Budget of the Office of Management and Budget in February, 1977, after having served as leader of the budget analysis group in President Carter's transition organization. From mid-1975 until the fall of 1976 he was Assistant to the President of the Washington Post Company, specializing in the area of corporate planning and budgeting. Prior to joining the Post, Mr. Cutter had been Executive Director of the Cable Television Information Center and Special Assistant to the President of Northwest Industries in Chicago. He was Staff and Research Director in the 1970 campaign of Senator Adlai Stevenson, and he was also a speech writer and campaign adviser for former Governor Dan Walker of Illinois.

Mr. Cutter graduated from Harvard College, and subsequently received a master's degree in anthropology and economics from Oxford University and in public administration from the Woodrow Wilson School at Princeton. For six years, he lectured in economics and public policy at the University of Chicago.

I am genuinely pleased to be here today because the eminence of the session has forced me to do some thinking about basic research and R&D and about OMB's and the federal budget's relationship to them. This is a topic which is certainly of great concern to you and ought to be to us. Also, I am genuinely pleased to be first on the program for a couple of reasons. I had breakfast this morning with Bill Nordhaus and we discovered that in some senses our talks paralleled, so that I'm pleased to be ahead of him. As the budget person in all of this, it's refreshing to be first. In the standard budget process, the advocates come first and then the budget person comes and gives the normal, ritualistic incantations about how we have to watch what we spend and winds up the heavy. Today I can do this at the start, and then Bill's comments will be refreshing to you.

I'll begin by being honest. There really hasn't been enough time for us to develop a clear policy with respect to R&D or basic research, and I might elaborate on why just to give you a sense, unrelated to R&D, about the beginnings of an OMB and the beginnings of the new Administration. Looking back now, we were faced with two unprecedented requirements for budget people, as the prior Administration unfolded and we began to take up our tasks.

The first of the two requirements was the timetable for the FY 1978 revisions to the Ford Administration budget. Always before, new Administrations in transitions were able to send up their new budgets in an incremental way. As I remember, Kennedy had something in the neighborhood of 68 major budget supplements that were strung out throughout his first calendar year in office. We would much prefer to have had it that way, from a physical point of view in any case. But the existence of the new Congressional budget process, which imposes a budget calendar on the major appropriation committees of Congress, by implication imposed a calendar on us. It wasn't a law, although it was sometimes mistakenly reported as that, but it was simply the practical fact of life that if we didn't get in one coherent document at a reasonably early time, our amendments to the FY 1978 Ford Administration budget wouldn't get considered in Congress. So the vast bulk of our work from the middle of November to the 22nd of February was taken up by the development of these revisions. Since there are people here who have been through that budget process in its normal period and phase, they can imagine what going through the same process in a month and a half with new cabinet secretaries, unaccustomed to the kinds of conflicts that the budget process raises, can do to you. We did not think profound thoughts during that period.

The second aspect of the budget process which has been imposed on us, although in this case we invited the imposition and we were awfully pleased to have had it, is the nature of our spring previews. I'll elaborate on this a little later. Normally, in the spring of each year OMB goes through what is largely an internal process of previewing the next fiscal year's major budget issues. (Just to get our years straight, we live in three fiscal years in any given time. Right at the moment, we are watching FY 1977 unfold, which ends the 1st of October of this year. On the 22nd of February we completed our FY 1978 budget revisions for the period October 1, 1977 to September 30, 1978. These proposals are now going through the appropriations process in the Congress. We are now planning the major budget issues for FY 1979, which begins in October, 1978.) This year, as the result of our suggestion and equally of the President's request, that process has culminated with the significant and lengthy participation of the President. We have now spent 24 hours in budget reviews with the President -- we will wind up spending 30 -- and preparing for the kinds of questions that the

President might ask has imposed an additional immense work load. All of which is by way of an apology that we did not develop a clear policy in the R&D area, but we have begun to think about it. My thinking won't strike you as particularly profound, but nevertheless it's a beginning.

Let me start with four conclusions, which represent, I think, where OMB institutionally has to come out. First, the federal government has a responsibility to fund basic research and R&D, both to solve national problems and to permit sustained economic growth. Second, however, OMB's dominant perspective regarding basic research and R&D must be programmatic and problem oriented. We have a responsibility to ask "what for" and "what are the specific terms." As Bill Carey well knows, as Willis Shapley well knows, you don't get very far in OMB by dealing with generalities. Third, this means that the budget process will be applied to R&D and basic research, as it must be, in the same way it is applied to all other expenditures. But despite this need for detailed supporting evidence, the fourth conclusion is that the federal government must concern itself not simply with the specific, case-by-case application or examination of issues, but with the adequacy of overall levels of basic research and of R&D.

These are probably obvious points. I look upon them as a sensible perspective, as the kind of view that we must have at OMB toward a topic like basic research and R&D. But threaded through them are two concerns: a concern with what a general level ought to be, what is adequate; and a particular concern with how to evaluate each piece of R&D or basic research that we have to weave into a policy which seems coherent when looked at both from the inside and the outside. It's those two concerns that I'd like to treat briefly now. I'll start by discussing federal investment and basic research as a public policy issue that poses difficulties for a federal budget maker. I'll probably say a lot of things you know already, but let me try to weave them together into a chain.

The first point is that basic research is undeniably a public issue. There is a four-part logic chain that leads me to this conclusion. First, as I am sure you are aware, there is strong evidence about the positive role of knowledge and of knowledge increases in economic growth. Dennison, of the Brookings Institution, has shown that one can explain about one-third of the growth of national income, GNP, by reference to the growth of knowledge, of technological change. Second, one can presume, it's a presumption I make in any case, that the knowledge base depends on basic research and R&D and, at least in a reasonable direct sense, on our investment in them. Third, there is considerable plausibility to the argument that the private sector will not invest sufficiently in basic research.

It is much more likely to invest in applied research and development. There are two reasons for this:

1. First, it is very difficult for a private firm, for one piece of the private sector, to be confident about appropriating the gains of successful basic research. I have been in charge in major corporations of capital investment, and one looks at rate of returns. I'm not talking about uncertainty so much as I am about the feeling within the company concerning whether it will appropriate the gains, even if a specific piece of basic research involves the elaboration of scientific laws, or maybe even the discovery of new ones, which are of limited patentability and which have such widespread application that no single investor can appropriate it. What this means, in terms of economic theory if one believes in marginal analysis, is that the private sector will never equate marginal gains with marginal cost.

2. The second point is uncertainty. Given the widespread nature of the gains from research, it is uncertain that any specific firm will get those gains. This is different than the issue of appropriations just described. Here I am referring to the uncertainty of when those gains will accrue, the uncertainty of where they will accrue, and the uncertainty of in what areas of research they will accrue. It is almost a level of effort argument. If one looks at the past, and one looks at returns over time, the returns to basic research have been enormous. In agricultural research it is estimated that the returns over time to basic research have been in the order of 700 percent, and this is a discounted rate of return. But, no one knew at the time where those would be, so that the social rate of return is likely to be considerably higher than any particular institutional rate of return.

And finally, one concludes from these statements that the public sector or the federal government must invest, if the social investment in basic research, in R&D, in science is to be sufficient. That's a four-part chain that leads me and certainly many others to the sense that there is a legitimacy to investment in this area. It requires our urgent, serious examination.

Second, there is ample reason to be concerned about trends. Over the past ten years, from 1965 through 1975, investment in R&D declined slightly and investment in basic research declined significantly in real terms. As measured by the budget, federal investment in basic research declined by 20 percent in real terms from 1967 to 1975. Since then it has increased, but that decline is an important and meaningful piece of data. Perhaps more importantly, basic research and R&D as proportions of GNP

have declined over that same period. Thus, if one believes the first point, that basic research is essential to sustain growth in the economy, than one has to be worried because of the second point, that basic research has declined. And there is some evidence that this decline has an impact. The evidence doesn't correlate terribly well, but for what it's worth and as Bill Nordhaus will also say to you, productivity in the postwar period has declined in each of the three decades. From the period of 1948 to 1955, the annual growth of productivity in the American economy was about 3.5 percent. From 1965 to 1976, that growth was about 1.9 percent. Now we don't know whether that's related specifically to basic research investment, to science investment, but the previous two arguments give one at least some reason to worry. If one is concerned about the role of capital formation in the economy -- and this Administration places a great deal of its economic reasoning and its economic logic on what we hope to be a future strength of capital formation -- and if one believes that capital formation basically depends on productivity, then one has to be worried about what will happen in the economy should the trends continue. All of this, in my judgment, clearly argues that the level of basic research and of R&D is an important public issue, and it's one that this Administration has to be, and will be, concerned about.

But all of the foregoing are general arguments. They are general agruments to the point that basic research is a legitimate form of public expenditure. But they are not arguments that tell us very much about "how much" and "what for," and unfortunately, we in OMB live in a world where one has to ask these questions, where competing claims outstrip resources, and where there are many legitimate competing elements and claimants to the federal budget.

Given the legitimacy of entering into the budget process, and given the necessity of R&D, one must ask what the budgeting process ought to be in general. What is truly difficult in the development of a budget as large and complex as the federal government's is to devise a process which on the one hand is sufficiently rigorous to force a detailed consideration of the competing expenditures and on the other hand does not lose track of major themes. It is easy to do each separately; it is terribly difficult to do them together. One can take a green eyeshade perspective toward the budget, an accounting perspective, and look at line items and that's not very hard to do at all. Or one can play statesman and look at the dominant perspectives of the budget. To weave them together into something coherent is terribly difficult, and yet not coincidentally, that is precisely what we have to do in many areas in a very major way for R&D and for basic research. We need a process that recognizes the underlying importance of the level of effort and still imposes real and rigorous programmatic constraints. Let me raise three aspects of the budget process as we are beginning to

look at it -- that should give you some reason for concern and also some reason for hope.

We start with the President who has made some commitments in the budget area that I think in many respects are far more specific and explicit and indicate a far higher level of interest in budgeting than most previous presidents. This President has made two very hard commitments and has evidenced an enormous amount of interest in a third aspect of budgeting.

In the first place, President Carter is strongly committed to a balanced budget at the end of his first term. I'll qualify that, it's a balanced budget with high employment. As Charlie Schultz has said, "We're not committing to be stupid." Whenever we look at federal government expenditures, we are looking at outlays with the idea of a balanced budget in mind. We think we are on a track where a balanced budget can be possible, but if something unexpected happens in future years, the President retains the latitude to change. The commitment at the moment is a very real one, however, and it means that perhaps even more than in the past, agencies and expenditures compete against each other. There is a very real sense that the funds for growth are finite and are going to be subject to rigorous examination.

The second commitment of this President is to process. This is the first governor to be a president in a long time. He is an executive, he understood and liked one specific budgeting process -- zero-base budgeting. It is that process through which we are going to trade off expenditures. We are currently putting that into place for the FY 1979 budget across the federal government as a whole. Zero-based budgeting has two aspects, both of which are concerned with processes for treating expenditures. The first is that it looks at not simply increments, but at entire expenditures including their rationale and alternatives. It is quite easy to think in terms of 3 percent, or any percent, of real growth for an area as a policy. In the course of the 24 hours of meetings with the President, I wince whenever the percent growth argument is made, either inadvertently by our side of the table or inadvertently by the agency's side of the table, because very frankly, the President doesn't like it. The President clearly likes to think in terms of explicit trade-offs, and explicit rationales, and explicit policies. The second aspect of zero-base budgeting that we will emphasize is the explicit ranking of programs. Although we understand the ambiguities and difficulties of ranking every program in something like HEW, we are imposing that it be done. In submitting budgets, the cabinet secretaries and subordinate officials on down the line will be asked to rank their decision packages, which is the term used for an examination of a specific issue. We won't accept all the rankings as they are. The President almost certainly won't accept all of our ideas of how the rankings ought to be. But we will argue about the rankings,

and we will use both the agencies' and our rankings to look at total programs. The rankings together with the explicit comparison of programs mean that programs, including basic research and R&D, will be subject to a highly rigorous look. And they must be.

I would think that at this point some of you might well be twiching because of these requirements. There are two reasons why one might argue that in some ways basic research and R&D are particularly vulnerable to casualty in this kind of comparative process. First, as you have probably heard over the last couple of years, a relatively low percentage -- 30 or 40 percent -- of the federal budget is controllable in direct budget terms. The rest consists of programs under which expenditures occur through continuing legislative authority. The Social Security appropriation, for example, is not one we debate a lot during the year. We may debate what the legislation with respect to Social Security ought to be, but the appropriations process is an estimating process. R&D and basic research have the misfortune of being completely controllable. They can be turned on or switched off. This leads, then, to the second point, which is that one doesn't really notice what one loses if R&D is switched off. I want hastily to say, however, that you do lose something. We recognize fully the legitimacy of the expenditures for R&D, but you don't recognize the fact the next year in programmatic terms. Therefore, one can well argue that basic research and R&D are peculiarly susceptible to being cut, because of their nature, through a process that is as rigorous as we hope ours will be.

What this means is that we need a means of concerning ourselves with the broad perspectives; that we can't simply wear green eyeshades throughout the budget process with respect to R&D. As I said at the start, there are two aspects of R&D expenditures, a national level of effort and a particularistic programmatic concern, that we have to contend with at the same time.

It is beacuse of the programmatic concerns that we began to think of, and more importantly, that the President began to think of and decided that he wanted, the spring process that I mentioned earlier. In addition to having a President who is as concerned with the detail of the budget as this one is, this President is also characterized in a number of other ways. He is highly analytical. I have a sense that his experience as an executive in the private sector as a small business man, and more importantly, as a governor, makes him different in some respects than other presidents. His approach to budget issues is disciplined and rigorous, but is also quite broad. And he believes in a highly open process. All of these characteristics are pertinent.

As I've said, we are now in the midst of the spring preview for the FY 1979 budget. As a matter of fact, we have finished the preview for the National Science Foundation; I think it was last Thursday. The President has involved himself in the previews in a completely unprecedented way. He has scheduled these 24 hours in the face of considerable scepticism among his own staff about the value of doing it, and he has included in those meetings a very wide range of people -- OMB officials, senior agency officials and senior White House staff -- all for the express purpose of airing major issues early.

It is interesting that the President at every meeting makes the point that he doesn't want to make decisions. What he wants to know are the kind of broad themes that underline and underlie the policy issues, the budget issues that we think will come up in the fall. In my judgment, what he's done is consciously used this period to examine the issues with a broader perspective than a normal budget process would allow and to begin to establish the themes for the FY 1979 budget. Without moderating at all his insistence upon detail and rigorous program evaluation, he has made very clear his concern in such areas as basic research and R&D that we not forget the broad perspective. He's asked us time and time again that we come back to him with quite detailed looks at broad problems; and that we retain for him the perspectives and the themes that he made explicit as we were talking about the problems. So while I can't tell you what will happen, and I know that the rigorous trading off of expenditures will surely cause you concern, I can tell you that the President has made explicit the fact that while he wants the trade-offs to occur, he also wants to see the general perspective.

Finally, I want to emphasize the point about the process being open. The most important reason that the President is aware of these more general concerns, particularly in the areas of basic research and of R&D, is the existence of Dr. Frank Press. Frank Press has been an important colleague in all of our discussions with the President. He's been involved in our more detailed consideration of budget issues; he is fully involved, and in many respects in the lead, in the consideration of how these current and longer-term R&D issues should be shaped for the President. While there have been concerns in the past about the status of science advice and the science advisers, I know that in this Administration the status is a vigorous and healthy and a widely involved one.

I want to thank you for the opportunity to speak with you.

William Nordhaus
Member
Council of Economic Advisers

William Nordhaus is currently serving as a member of the President's Council of Economic Advisers while on leave from Yale University. He has been a member of the Yale Economics Department since 1967 and has also spent time at Cambridge University, at the International Institute for Applied Systems Analysis in Austria, and at the National Bureau of Economic Research.

Professor Nordhaus' economic research has concentrated on macroeconomics, growth economics, and resource and energy economics. In the latter area, he is the author of a number of studies on the efficient use of energy resources. In the field of macroeconomics, he has studied the process of inflation, productivity, and wage determination. In growth economics, Professor Nordhaus has been one of the main critics of the Limits to Growth School, as well as introducing a different outlook on the measurement of growth. He is the author, with James Tobin, of a new technique for the measurement of economic growth, the Measure of Economic Welfare, MEW.

Professor Nordhaus received his B.A. from Yale and his Ph.D. in economics from Massachusetts Institute of Technology.

The Role of Research in Economic Growth

It is instructive for an incoming Administration to look back to earlier periods to see how little concerns have changed. The parallels of the current economic period to those of the early months and years of the Kennedy Administration are uncanny. At that time as now, unemployment was extremely high; there were widespread fears of inflation; business confidence in the new Administration was insecure; and large recession induced budgetary deficits were being derided in the financial community. Even the steel industry was being kicked around.

In one area, however, there has been a fundamental shift in values. A decade and a half ago, economic growth was the centerpiece in the long-term economic policy of governments in the country and abroad. For clarification, let me stress that by economic growth I mean growth in the high employment level of output, or what is technically termed the "potential output" of the economy; I do not refer here to the recovery of the actual

output back to its potential level, a recovery which we are trying to effect over the next four years.

It is clear that the public perception, and even more importantly the scientific perception, of the nature and role of economic growth has changed dramatically. In contrast to a decade ago, it has now become fashionable in a wide variety of circles to question the merits of further growth. Why is it that economic growth is no longer believed to be either feasible or desirable?

1. First, the limits to growth debate has convinced many that we have reached, or perhaps exceeded, the levels of output which are sustainable in the long run.

2. At the same time, people have begun to reckon up the "costs of growth" -- the environmental degradation, congestion, urban and moral decay -- and to question whether the game is worth the candle.

This is not the forum in which to have an extensive discussion of these issues. Briefly, however, there are answers to many, if not all, the issues raised by those who question economic growth:

1. There is good reason to think that the advocates of the limits to growth position have systematically underestimated the resource base, substitution possibilities, and -- my theme today -- the potential for technological improvement in our economy.

2. Moreover, to those who question the desirability of growth, I suggest that the proper goal for economic growth is not an imperfect measuring device like the Gross National Product, but a goal like "Net Economic Welfare." N.E.W. measures the growth in goods and services corrected for the social and non-market costs that are the undesirable side effects of economic growth.

Debate continues on these and other issues surrounding growth, and I cannot pretend to answer these all today. Nevertheless, it is useful to review where we now stand. More specifically, I would like to address two questions: What are the sources of economic growth, and in particular, what is the role of new knowledge, or technological change, in the long-term growth of living standards? Second, what is the appropriate federal role for support of research and development designed to promote growth in knowledge and technological change?

Consider first the contribution of technological advance to economic growth. Without question, technological advance is a key input into the process of achieving increases in productivity.

Technological advance enables us to use resources more efficiently; to get more amenity or output from the same BTU's; to find new uses for existing resources; to find uses for previously "useless" materials and concepts; to create new types of goods, and to improve old ones. In short, whether in defense or civilian life, new technologies enable society to get "more bang for the buck."

And further -- probably to a much greater degree than other types of resources -- technological advance provides the seeds for its own extension. Technological advances in one field facilitate further advances, not only in that field, but also in related ones. In this age of scarcity, it is comforting to know that, unlike other scarce goods, knowledge is not a depletable resource. No matter how many times the second law of thermodynamics is used or abused, it will remain for future generations to use and abuse.

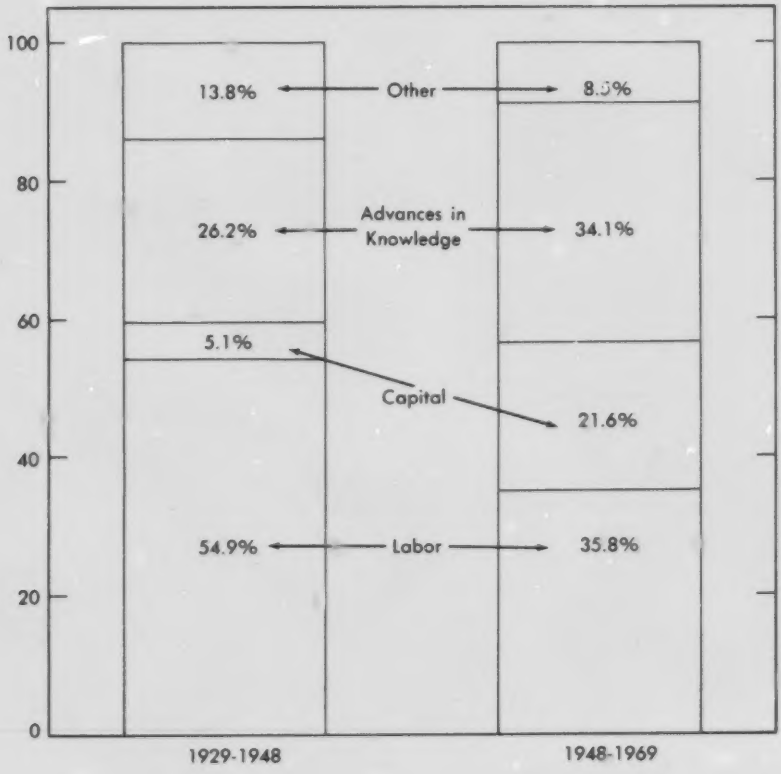
How important is technological change in economic growth? Early studies, one by Professor Solow, indicated that almost 90 percent of the long-term increase in per capita output could be attributed to technical change, rather than to increases in capital or labor supply. Other early studies in specific areas revealed enormous social rates of returns to investment in technical advance -- even after accounting for unfruitful pursuits.

More recent work -- especially that done by Dr. Edward Denison of the Brookings Institution -- indicates that technological advance, or the growth of knowledge, has been second only to labor supply increases as a major source of economic growth over both short and long periods since 1929. Figure 1 shows the breakdown of major sources of growth. The effect of technological change substantially outweighs that of increases in capital stock. For example, Denison estimated that advances in knowledge accounted for 31 percent of the increase in national income from 1929 to 1969. For the postwar period, 1948-69, the figure is 34 percent. For shorter periods, the conclusions are identical. From 1929-41, technological advance accounted for 20 percent of total national income growth. The figure for 1964-69 is 24 percent.

One highly surprising by-product of this research on growth is the relative importance of some problems which have long been high on the public agenda. For example, it will probably astound most people to learn that the efficiency losses due to monopoly are, according to Denison, about two orders of magnitude smaller than the gains to technology. He estimates that if the static efficiency losses due to monopoly or imperfect competition in product markets were eliminated, this would add only approximately .03 percent annually to our growth rate over the next 20 years.

FIGURE 1

Percent Contributions to Economic Growth
of
Labor Input, Capital Input, and Advances in Knowledge



These results are sufficient to convince most analysts that the role of research and development and technological change in the economy is paramount. But does this automatically imply that we are currently allocating too little to research and development? What should be the federal role in bringing about technical change through government funded R&D? Why should tax dollars be spent to further technological advance when there are so many other uses for very scarce public funds? If technical advance generates such substantial productivity increases, won't the private sector allocate optimal quantities of resources to R&D? If we rely on profit incentives for most activities, why not also for technical development?

The answers to these questions are basically that the organization, profit incentives, and uncertainty inherent in research and development, especially in basic research, are quite different from those in normal economic goods and services. I will address only two of the most important differences, the "nonappropriability problem" and the uncertainty problem.

First, the social benefits of much -- but not all -- R&D exceed the private benefits. This means that not all the social benefits can be privately appropriated. To put it differently, private inventors or investors do not capture all the social benefits of investments in technical advance. The invention of the transistor was profitable to Bell Labs, to be sure. But the transistor also made possible further discoveries and a multitude of new products which produce benefits far beyond those ever captured by the original inventors.

As a result, there is good reason to suspect that there will be underinvestment by the private sector in R&D -- for the marginal social returns are likely to exceed the cost of capital used to fund those investments. This is likely to be especially true in basic or pure research, as opposed to applied research, development, or commercialization:

1. Advances arising out of basic research are likely to apply to a very wide range of fields.

2. Enforcement of property rights in knowledge gained through basic research over so wide a range of activities is likely to be extremely difficult.

3. Advances arising out of basic research are likely to include unpatentable "laws of nature."

4. The complexity of modern technology makes for patent rights which are difficult to define and therefore difficult to appropriate.

The history of discovery is filled with other examples of individuals or groups who gained but a small fraction of the benefits from their discoveries: Alexander Fleming certainly recovered but a small fraction of the benefits of penicillin. Similarly, the inventor of xerography has been unable to capture all of the gains from xerography felt by secretaries all over the world. Recall for a moment the gains from technical change we showed in Figure 1. It is clear that these benefits have largely accrued to consumers in the form of lower prices rather than to firms in the form of higher profits. Imagine what would happen if investors tried by lobbying and advertisement to get all their rents in a fashion similar to that of the oil and gas industry: we would be deluged with a lobbying effort at the Richter lobbying scale 10 rather than today's scale 7.

The second reason why the federal government has a special role in research arises out of the highly risky nature of R&D investments. By its very nature, investment in technical advance is an uncertain endeavor. Those undertaking it cannot know with a high degree of confidence whether it will succeed. This problem is especially acute for basic research; not only is success uncertain, but the goals of basic research are likely to be quite general. Thus, one cannot be sure of the end results themselves, let alone the probabilities of their successful attainment.

Since success is uncertain -- much more uncertain than that of other private investments -- private firms considering an investment in R&D will undertake it only if the expected returns are sufficiently high to justify the risk. An expectation of a normal return will not suffice; above normal or supernormal expectations are necessary. This problem may be less acute for larger firms undertaking R&D in several areas, reducing their risk through diversification.

However, this private diversification is not likely to eliminate completely the uncertainty problem for private sector decisions. No firm or industry is likely to consider a range of R&D activities wide enough to eliminate uncertainty as a significant factor in their R&D investment decisions. Put simply, private sector R&D investment will generally be undertaken only with the expectation of greater than normal returns. These decisions are privately efficient; the question is, "Are they socially efficient?" The answer is "no." For society as a whole, so many projects in technical advance are undertaken -- in so many diverse fields -- that society's "portfolio" of investment projects is virtually riskless. Society as a whole is analogous to an insurance company: it knows that over reasonable periods of time, successes and failures will wash; a normal rate of return for the entire group of projects is virtually certain. In short, social efficiency dictates that R&D projects be undertaken if the expected returns are at least normal; private risk provides firms

with a socially inefficient decision-rule. Thus, this bias operates in the same direction as the nonappropriability problem I discussed earlier: private sector investment in technical advance will generally be too small.

Consider some examples. Figure 2 compares estimated annual real rates of return to corporate capital with estimated annual rates of return to R&D in hybrid corn development. Private investment in the nonfinancial corporate sector over the postwar period earned a real before-tax return of about 13 percent. Hybrid corn research and development, funded in substantial part with public money, was estimated by Professor Zvi Griliches to have earned a social rate of return of at least 700 percent. All agricultural R&D -- including unsuccessful endeavors -- was estimated to have a median social return of 103 percent. Private sector R&D investments also seem to generate high social rates of return: a study of chemical and petroleum research gives an average return for 10 chemical and petroleum firms of 47.5 percent.

Both the nonappropriability and uncertainty problems are likely to be especially acute for basic research: it is very difficult to capture the returns to basic research, many of which are highly uncertain. Moreover, uncertainty about the goals of basic research increases uncertainty about outcomes. Unless we are to throw our hands up in despair, we must turn to alternative institutional arrangements for the promotion of technical advance. In the process of exploring such an alternative, consider the following two questions: First, what patterns of public and private participation in R&D activities have existed in the past? And, second, what changes, if any, can be suggested for the federal effort in the future?

Armchair economics suggests that the bulk of private R&D would be directed toward applied research or to development. Evidence bears out this expectation. In 1976, for example, industry performed 54 percent of the applied research and almost 86 percent of the development done in the United States. Industry financed 41 percent of the applied research and 50 percent of the development. On the other hand, industry performed 16 percent and financed only 15 percent of the nation's basic research.

These data suggest that expenditures of the federal government would be most productive if they emphasized basic research. And yet the recent behavior of the federal government is not consistent with general principles. The basic data are shown in Figures 3 and 4. Total federal real expenditures on basic research decreased from 1965 until 1976, as is seen in Figure 3. Real federal 1976 spending on basic research was almost 22 percent below that of 1970. Even more startling is the fact that basic research expenditures, as a percentage of GNP, have declined steadily from 1965, declining over 24 percent. This is shown in

FIGURE 2

Estimated Real Rates of Return to Investments
in
Nonfinancial Firms and Agricultural Research and Development

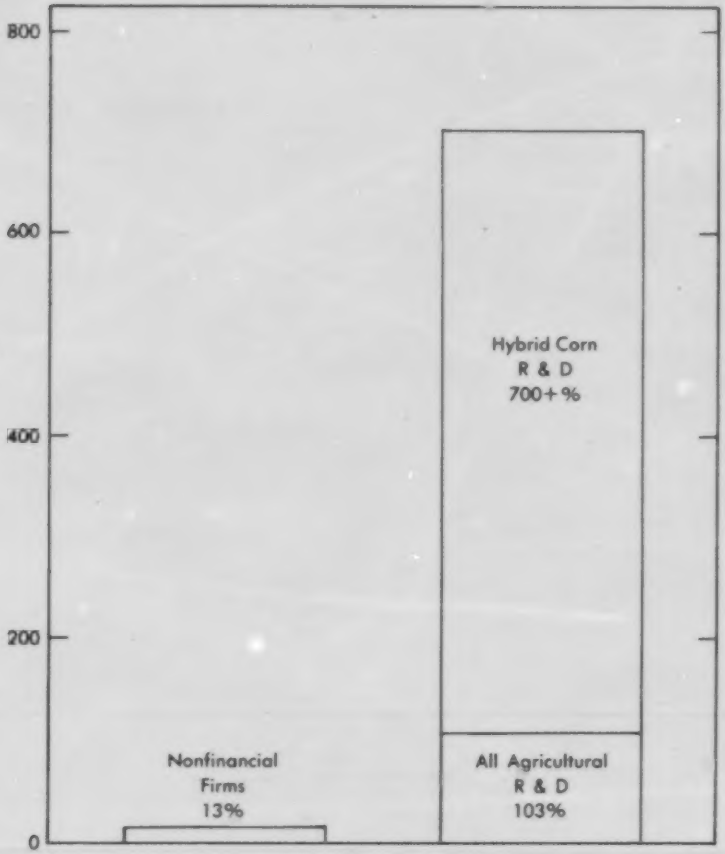


FIGURE 3

Basic and Total Federal R & D Expenditures

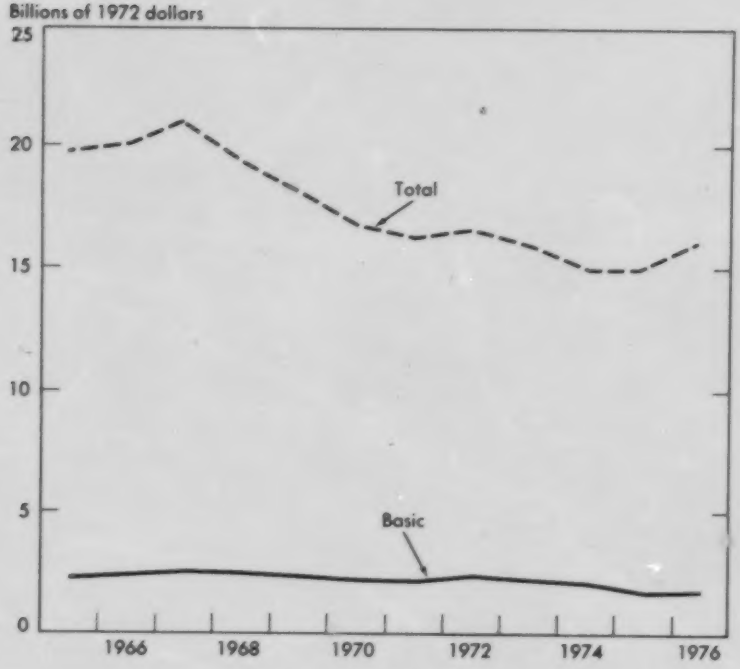


FIGURE 4

Basic and Total Federal R & D Expenditures as a Percentage of Gross National Product

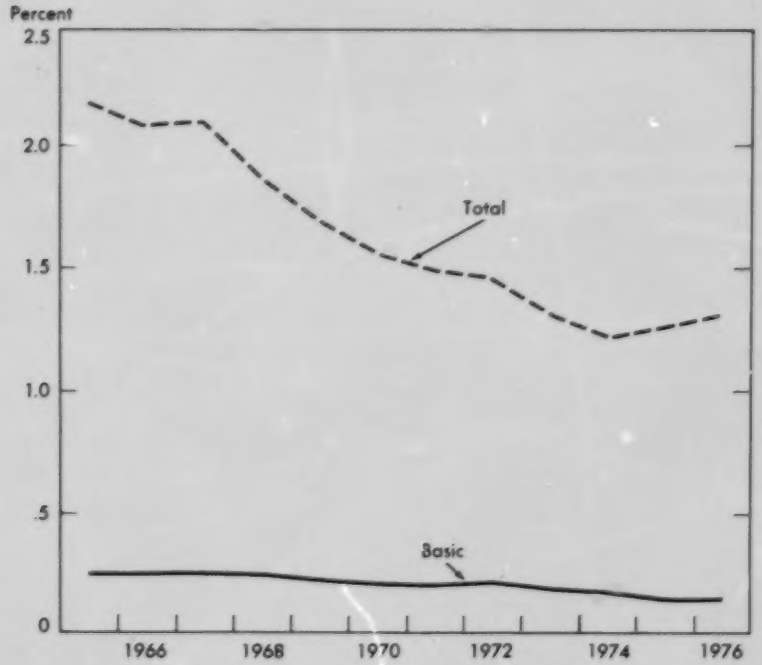


Figure 4. This decrease has been due primarily to a decline in total federal spending for R&D, which has fallen by about 18 percent since 1965.

It is sobering to relate the trends in federal support to recent productivity trends in the American economy. There has by now accumulated a great deal of evidence that the economy's productivity growth has slowed significantly over the postwar period. The following shows the average annual growth in output per person-hour for the total private business economy in the United States:

Period	Average Annual Growth in Productivity per Person-hour
1948-55	3.5 percent
1955-65	3.2 percent
1965-76	1.9 percent

The slowdown is most dramatic in the period since 1965, especially since 1973. In part, the slow growth over the last decade reflects the poor health of the economy in the terminal year; but there can be no doubt that productivity growth has decelerated at an alarming rate.

In light of our earlier findings about the importance of new knowledge in economic growth, as well as sharp decline in the federal support for research and development, it is tempting to point the finger at the low levels of support as an important causal factor in the productivity growth slowdown. Unfortunately, the statistical linkage has not been made, so we can only suspect the connection.

One area where public and scientific interest in research and development has been running high is, of course, for energy. The level of concern is clearly reflected in the recent sharp increase in the total federal budget for energy research and development. As Figure 5 shows, since 1973 the total energy R&D budget (in 1972 prices) has increased from $400 million to over $1400 million. As a percentage of all nonmilitary and non-space federal R&D, energy R&D has climbed from approximately 8 percent in 1972 to almost 25 percent. This is illustrated in Figure 6. Clearly energy has been accorded the center of the R&D stage.

Yet with all this federal attention devoted toward energy R&D, basic research has fared no better than elsewhere. Figure 5 indicates that the absolute level of real basic research in energy funded by the federal government has actually fallen since 1969. Figure 6 illustrates that, as a fraction of all federal basic research, the share devoted to basic energy has also declined over the same period. The message is clear: federal

FIGURE 5

Basic and Total Federal R & D Expenditures on Energy

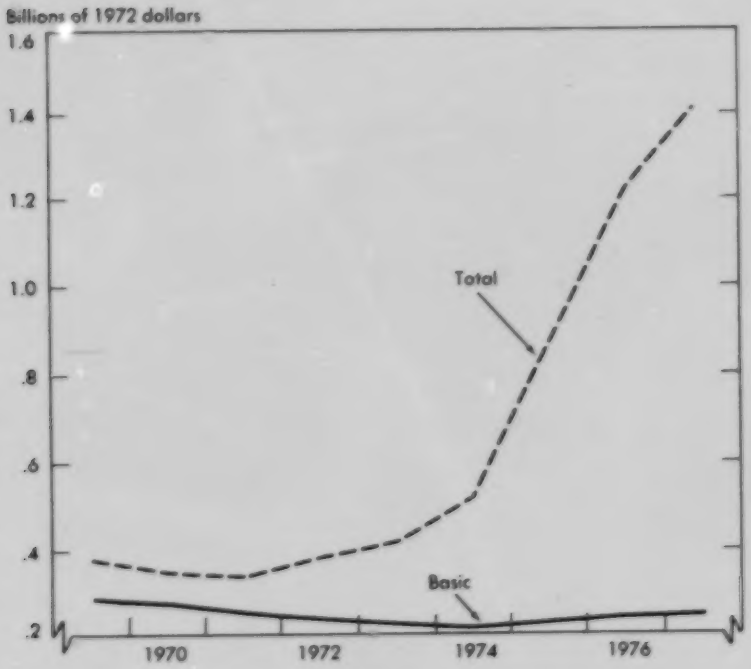
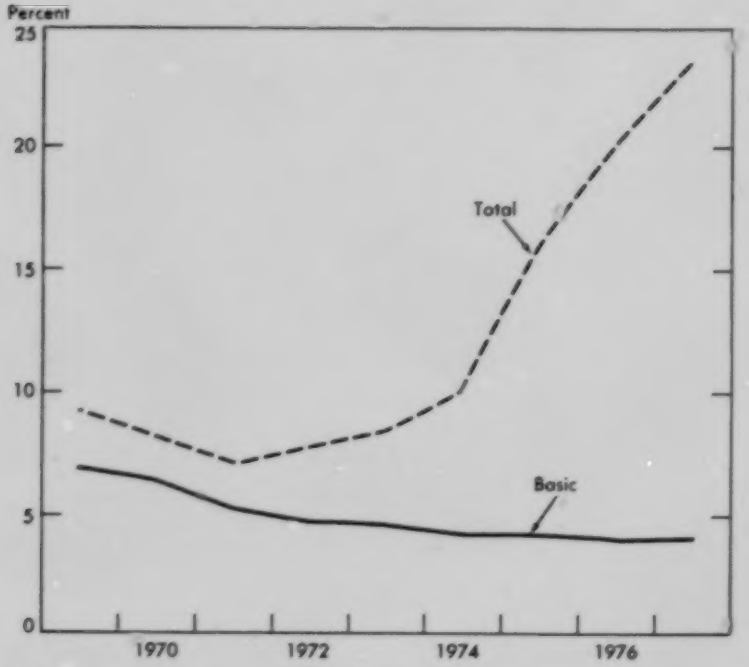


FIGURE 6

Federal Energy R & D Expenditures as a Percentage of All Federal R & D



funding of energy R&D has moved away from R and toward D.

In the decision of the Carter Administration to retrench somewhat on the breeder reactor, we may now be seeing some rethinking of principles for the support of research and development. Budgeted to cost close to $2 billion, the proposed demonstration plant for the Liquid Metal Fast Breeder Reactor (LMFBR) at Clinch River, Tennessee, constituted a major portion of the federal R&D budget for both 1977 and 1978, and was a major force impelling the total federal energy R&D budget upward over the last few years. By indefinitely halting construction but continuing basic research, the Administration moved toward the kind of policy that I have described so far today. Similar reasoning raises questions about the use of federal funds for commercialization projects in other parts of the energy sector.

In general, one would like to see greater federal attention paid to that part of the R&D process where the private sector is likely to do the poorest job -- namely in basic research. In moving away from financing development and commercialization, we can encourage decision-making and risk taking by those already accustomed to making those kind of decisions, and, most important, not prejudge the outcome of the race between competing technologies.

To summarize, I have tried to suggest today that science and research are both central to the long-term growth in living standards and why problems of market failure indicate a need for an active role for the federal government. There remains, however, a central problem which is the management of the direction of science and research itself. On the one hand, how can we make sure that funds are efficiently used when they are not subject to the discipline of market forces? On the other hand, how can we guarantee the choice of sound projects when they are subject to the discipline of political forces? It is sobering to ask, who in the public or private sector today would be irresponsible enough to fund a project on Galapogos finches? Yet the central task of managing research is just that.

Luncheon Address

Robert Hirsch
Deputy Manager for
Science and Technology
EXXON Corporation

Robert Hirsch became Deputy Manager of the Science and Technology Department of EXXON Corporation in March, 1977. Since February, 1976, he had been Assistant Administrator for Solar, Geothermal and Advanced Energy Systems of the Energy Research and Development Administration.

After obtaining degrees in mechanical and nuclear engineering, Dr. Hirsch worked in various aspects of fission reactor research and development for a short time until he changed his career direction to work in fusion power research and development. Accordingly, he returned to school to obtain a Ph.D. in plasma physics. He then did experimental fusion plasma physics at the ITT Industrial Laboratories and in 1968 joined the Atomic Energy Commission as a staff physicist in the fusion program. In 1972 he was appointed director of the magnetic confinement fusion program, a position he held until he became assistant administrator.

Dr. Hirsch has received several distinguished service awards, and he has held offices in many national and international fusion research organizations. He holds twelve patents and is the author of a number of technical publications.

On the Nontechnical Problems of Energy R&D

Energy research and development is not the innocuous subject that many think it to be. Like the whole energy problem, energy R&D is the subject of significant debate. With respect to the federal energy R&D budget, seemingly small items actually represent issues of principle to many.

Today I would like to take a somewhat different approach to analyzing energy R&D problems and in the process hopefully provide some new perspective -- perspective that might prove useful in future thinking and discussions. In what follows, I will approach the nontechnical problems of energy R&D in the same way we might approach a scientific or engineering problem. First, there is a need for a clear statement of the problem. Next, we

need to identify the givens, variables, and boundary conditions. Because we are addressing a nontechnical problem that involves people and institutions, it is important to identify the obvious conflicts and issues.

After doing this, we will find that we have more variables than simultaneous equations to solve our problem so we must make some assumptions before we can arrive at a solution. The solution I will outline will be what I consider to be a widespread industrial point of view on energy R&D. The major point I will attempt to make is that industry believes that federal energy R&D ought to be concentrated on the high-risk, expensive, long-term options plus basic energy science research. Industry generally is happy to handle the nearer-term, normal risk problems, provided the government removes the disincentives that it has created. Finally, because few people can, or would, simply leave the table and go implement a luncheon speaker's "grand plan," I will issue a more manageable challenge to the government -- a challenge which picks up on something that the President emphasized during his campaign.

The issues that I will present are complex and involve a great many details; that is not the most desirable thing on a full stomach, but let us give it a try.

The Problem

The purposes of energy R&D are to develop methods to conserve energy; to develop new energy sources and/or converters that are more efficient, lower in cost, and/or environmentally superior to existing forms; and to develop new energy sources that utilize fuels that are more abundant than existing, depleting fuels. The range of activities covered is extremely broad. It extends from product and process improvement to the development of totally new forms of energy; it covers everything from developing improved means to drill for oil in deeper water offshore, to stack gas cleaning, to coal liquefaction development, to fusion R&D. These widely varying activities require a broad range of human talents and the harmonious participation of a number of different institutions.

Energy R&D is not an end in itself, at least not to most of us. We do energy R&D because we have a larger problem to solve -- the so-called "energy crisis." To solve this problem we must not only make new discoveries and develop new technologies but we must bring them to the marketplace. So a critical element of effective energy R&D is an optimal connection to a product or process delivery system.

But I said we need a clear statement of the problem, and so I propose the following:

From a nontechnical standpoint, determine the best way(s) for the country to conduct its energy research and development.

The Givens

Having a problem statement, let us attempt to identify the important "givens." As we go through this list, you will unfortunately note some variability in each of them, but that cannot be avoided as best I can see.

The first "givens" are the various energy technologies. These cluster about oil, gas, fission, coal, solar, geothermal, fusion and the so-called conservation technologies. Each of these is characterized by a different technical state-of-the-art, commercial maturity, and industrial infrastructure. For instance,

1. Oil and gas are scientifically well characterized. Their handling, processing and use are extremely well developed and the basis of a very competitive industry. For instance, as big as EXXON Corporation is, it produces only about 1 million barrels of crude per day in the United States, refines about 1.3 million barrels of oil per day and sells about 1.8 million barrels of product per day in the U.S. market. Since present U.S. consumption is about 18 million barrels per day, that says that the country's biggest oil company is responsible for about 10 percent of U.S. sales and less for production and refining. That is a pretty competitive situation!

2. The fission industry employs highly sophisticated and well developed technology. In commercial terms, this industry has not reached full maturity. For instance, disposal of spent reactor fuel remains to be commercialized, although the technology to do this does exist. Most of this industry -- uranium production, reactor manufacturing, and fuel fabrication -- is in the private sector, but a major element -- uranium enrichment -- is a government monopoly.

3. Coal is a somewhat different ball game in a number of respects. Coal science is largely empirical. Much is still to be learned about the details of coal combustion and coal transformation to liquids and gases. The mining and transportation aspects are mature and are being capably handled by industry. The direct and indirect uses of coal go back many years on the one hand, but on the other hand many coal burning and conversion systems are not yet acceptably developed from the environmental and/or the cost standpoints.

4. Solar energy has been powering this planet since the beginning of time, but we are just now beginning on a large scale to apply modern methods to its development and its more direct use.

5. Geothermal energy in the form of hot, dry steam has been used for centuries for a variety of purposes. Its application to electric power production goes back decades. But the use of hydrothermal and geopressured geothermal for electric power production is relatively new.

6. Fusion is the primary source of energy in our universe. However, fusion R&D is a highly sophisticated, expensive scientific R&D effort. No industry exists and will not for many years to come.

7. The conservation technologies vary widely with respect to basic knowledge, industrial sophistication, and industrial capability to meet the new efficiency and environmental challenges.

The next important "given" is the institutional structure that exists in energy. There are the energy supply companies, such as the oil, gas, coal, and uranium supplies. There are the equipment suppliers that provide generation, conversion, transmission and utilization equipment. There are the low-to-high-technology, non-energy related companies that may become "new players." There are the national laboratiories and the universities. There are the Electric Power Research Institute and the newly formed Gas Research Institute. There is the government -- the White House, the Congress, ERDA, NASA, EPA, NRC, FPC, Interior, OMB, soon DOE, etc. There are two powerful new arrivals on the scene: the environmental and public interest groups. And last, but not least, there is OPEC. These institutions are "given."

Next, we also have people as "givens." The country has a tremendous pool of scientific, engineering, managerial, and labor talent. A significant number of these people are involved in energy, and many more are capable of contributing with anywhere from modest to significant retraining, that is, the size of the energy manpower pool can change depending upon need. Also, people can move from organization to organization and region to region depending on needs.

Finally, there is the country's physical plant. We have factories that fabricate a whole slew of different products from boilers to pressure vessels to turbines to generators to instruments to fission fuel rods, etc. There are common to uncommon testing facilities ranging from relatively simple air sampling stations to the Nevada Test Site for Weapons. But again there

is a variability in this "given" because new physical plant is added and retired according to needs, age and capital availability.

That completes my list of "givens." You might want to add a few more items, but before you do, wait until we run through my list of variables.

The Variables

When we turn to the "variables," we begin to see the issues emerge. In the interest of time, I can only touch lightly on each variable. As a colleague pointed out to me, we could spend a day or more on a number of these.

1. Emphasis. What are we really trying to accomplish with energy R&D? Are we trying to switch the country off of its dependence on oil and gas? How fast? Are we trying to reduce our dependence on imports? How fast? Are we trying to convert to coal and fission? Are we trying to reduce the environmental effects of energy? Are we trying to keep costs down? Are we trying to maintain our present standard of living or allow flexibility to expand? Are we trying to get to the inexhaustibles (solar, fusion and/or the breeder) as soon as possible? Are we trying to increase our energy efficiency so as to cut down on our fuel needs? Are we trying to right the "sins" of waste of the past? Are we trying to expand or to conserve? Are we really aiming to convert to solar energy to help purify our world? To what extent are we driven by national security motivations? And the list goes on. I have talked with a number of people in and out of Washington and found a number of different answers to these and related questions, and these views lead to differing priorities in energy R&D.

2. Timing. How much time does the country have to switch from oil and gas to alternate fuels? Many studies say that the demand-supply crunch will not come until the 1990's. On the other hand, the Workshop on Alternate Energy Strategies (WAES) created a scenario wherein we could be in trouble as early as 1981. Presently, the country is going about its energy business as if the problem will become severe in the year 2000 or beyond. On the other hand, if the country believed the problem would be severe in 1981, it would be mobilizing like it did in World War II, say, for the development and production of synthetic rubber. So timing can have a major effect on our approach.

3. Funding. Hand in hand with the question of emphasis and timing is the question of R&D funding. If we think we

have until the year 2020 to significantly reduce our dependence on oil and natural gas, we would be spending the kind of total government and industry dollars you see today. On the other hand, if that degree of change-over were needed by 1985-1990, we would have to be almost on a wartime footing now, spending maybe five times present levels.

Once total funding is established, the quesiton becomes one of the optimum sources of the support. What fraction of total dollars for a particular development should come from the government, say in the form of an ERDA contract, and what fraction should be supported by corporate funds? Surely the answer varies according to technology, risk, magnitude of the required funds, time to commercialization, importance to the national program, etc.

4. Location of the Work. What should we do in the universities? In the national laboratories? How much should we do in industry? When government funds are involved, how many competitors should be supported in parallel?

   When work begins and/or develops in a university or a national laboratory, how do we ensure that it is transferred to industry on a timely and effective basis? How can we optimally retain the vigor, enthusiasm, and experience of the early workers when a project is transferred to an industrial laboratory? These and related questions are critical to success, and yet the government has essentially no relevant experience in such matters.

5. Government Policies. Here we get involved in a maze of variables:

   a. Regulatory Policy. Is energy to be priced by the market place or by government regulations? If we operate in a free market situation, industry will spend much more on energy R&D than it can in a very uncertain regulated situation. If a reasonable return is not possible on a new process or product, then industry would not do the necessary R&D to develop it, nor will industry use the results that come from related government R&D, that is, without proper market incentives, industry will not commercialize a new process or product independent of who supports the R&D.

   b. Tax Policy. Are we going to provide tax incentives for the private sector to spend its own money for the energy R&D it deems most desirable or are we going to directly fund the bulk of the country's R&D from ERDA? Or are we going to aim for some middle ground?

c. Environmental and Safety Standards. Must we continue to evolve new, tighter environmental standdards with their associated uncertainties or can we set some reasonable, fixed targets and introduce some more certainty? When will we be able to fix our targets? When will we decide what is safe for nuclear reactors? When will we begin to do cost-benefit analysis to trade off tighter environmental standards against greater supply?

6. Social Changes. To what extent do we want to use energy and energy R&D to alter the structure of our society? We are all aware that there are groups pushing the so-called "soft" energy technologies in part as a means to alter our industrial infrastructure. Others believe that energy is so important that the government ought to have even greater control of it -- a national energy company, more TVA's, etc.

   Next time you get into a discussion with someone who advocates signigicant changes in the way we handle energy R&D, take some time to try to find out if they basically believe in our present free enterprise system and try to find out if they believe in free enterprise in energy. There are a number of people and groups advocating changes in our society, and some of them hope to accomplish their objectives in part through changes in energy policy.

7. Government Employee Attitudes. Some think policy is made on high in government, and the staff follows. That is not always the case, of course. In ERDA, for instance, you will find differing attitudes and approaches to energy R&D in each program division and often times inside a division. Some program managers feel their job is to help industry develop and commercialize a particular concept. These people worry about institutional barriers as well as technology, and so they work from their unique position inside government to help solve these problems. The ERDA Division of Geothermal Energy is an excellent example of this approach.

   In other cases, program managers feel that they are responsible for essentially the total U.S. program in their particular technonogy; they consider themselves national managers. The Division of Magnetic Fusion Energy is a good example of this approach. Here industry has a very small stake, and I believe (understandably!) the approach is fully justified. On the other hand, there are a number of much more applied, near-commercial programs where the managers are taking this same point of

view and are encroaching on industry's traditional role and responsibilities; these situations are unhealthy.

8. Accountability for the Use of Public Funds. Some government overmanagement and delays in contracting are a result of the pressure that accompanies the intense scrutiny by the OMB, the Congress, and public interest groups of the use of public funds. This pressure introduces varying distortions, some of which can get rather extreme.

Assumptions, Conflicts and Issues

Assumptions.

Now, like any good scientist faced with more variables than simultaneous equations, it is necessary to make some assumptions in order to create a tractable problem. Hopefully, in doing this we make the right choices so that we end up solving the right problem. My choices are as follows:

1. I assume that the country still believes in competition and free enterprise as the best means to provide the public the lowest cost product in adequate quantity and quality. This means that I am rejecting the possibility that the government will take over more of the energy business and I am assuming (somewhat uneasily!) that there will be no divestiture of the major energy companies. On this basis, plus or minus tax incentives or regulations that enhance some technologies, the market price will generally determine what technologies receive the greatest use. Lastly, this assumption means that industry will remain as the commercializer or deliverer of the ultimate product. This requires the government to act differently in energy R&D than it has in space or defense R&D, where the government is the ultimate and only customer and where cost generally plays a secondary role.

2. Next I assume that the country will not use energy as a means of major social and institutional change. I suppose this really follows from my first assumption. It says the "soft" versus "hard" technology debate will be resolved primarily by the cost and market preferences for the technologies that are developed in each category.

3. I assume that the national laboratories are a national asset and will continue to play a useful role in energy R&D.

4. I assume that we are not going to settle our environmental problems quickly. Man's yearning for purity and

protection plus our relatively crude understanding of the effects of pollutants plus the very strong environmental lobby to me mean that environmental issues will not be simply resolved for some time to come.

5. I assume that normal dialogue and pressures will keep government and industry working together on a reasonable basis with a reasonable degree of trust, and I assume that repititious scrutiny and burdensome reporting procedures associated with public expenditures will not get worse, causing even greater distortions in government-industry relationships. Of course I wish that the situation in the United States was more like that in Japan or Germany where government and industry trust one another and work together closely.

Conflicts and Issues.

Having made these assumptions, and in some cases praying that I am right, we can turn to the major conflicts and issues. In my view, these are associated with funding levels, funding source, location of the work, method of government stimulation, and environmental trade-offs.

1. With respect to total national level of energy R&D, I personally believe we are still not spending enough. I am deeply concerned that the country is moving too slowly. Too high a level of expenditure would clearly be inefficient and wasteful. On the other hand, if we move too slowly, by definition we will reach a point when we will have to accelerate considerably and in so doing, we will be much more inefficient and wasteful. If we as a country are successful sooner than absolutely necessary, that generally will just insure greater efficiency and adequate supply, which will cut down on imports -- that hazardous elastic element that keeps growing and growing as we take longer and longer to decide what to do.

2. What about funding source? The ultimate provider of funds is the consumer-taxpayer who provides support through payment for his energy products and his taxes. Part of the consumers' payments for energy products goes to industrial energy research and development and part of the consumers' taxes goes for direct government funding for R&D. The issue is then what fraction of the total energy R&D budget should come indirectly from the government thereby being subject to government control.

3. What fraction of the national energy R&D dollar should be spent in the universities, in the national laboratories, and in industry? Under the previous assumptions,

as a product nears commercialization it must move into industry. But how do we ensure optimum movement, particularly when the government has little experience in commercializing technologies and the natural tendency of researchers is "to hold on"?

4. Next, what is the best way for government to stimulate the energy industry to be more aggressive in its sponsorship of energy R&D? Larger tax incentives are one way. Another path involves a very politically touchy issue, that of energy price regulation. Over the course of the years the country has evolved an incredibly complex and cumbersome regulatory system, in part for reasons that could be at least partially justified at the time. Many of our regulators themselves recommend abolishment of much of our regulatory system; it is simply not capable of responding to the rapidly changing circumstances of today. One negative associated with our present regulatory system is that it introduces so many time varying inequities and uncertainties that industry is unable to effectively predict future trends and costs, so it takes fewer risks and does less R&D than it would if new energy were unregulated. Is this in the country's best interest? Are the benefits worth the costs?

5. Finally, there are the changing environmental/safety standards. These introduce major uncertainties that affect many industry activities, including R&D. The most extreme example is probably the nuclear industry, which some believe is teetering on the edge of extinction in part because of environmental/safety hassles.

Boundary Conditions

It is hard for me to identify some clear boundary conditions on the energy R&D problem. One boundary condition might be that total R&D dollars stay below some maximum level. But energy is a survival need, so what upper bounds would you set, particularly in light of the fact that R&D dollars represent a small part of what's ultimately required to commercialize a new technology?

Another possible boundary condition might be that industry must always commercialize new energy technologies. That's probably a more acceptable boundary condition, unless maybe you're a socialist. At any rate, I couldn't do much in the boundary condition department in part because I allowed so many variables in my problem development.

A Widespread Industrial Point of View

In an attempt to identify an industrial point of view for this presentation, I contacted people inside of EXXON as

well as some friends outside. As best I can tell, the following represents a reasonably widespread view. I have organized these next remarks into the following categories: Need for a total energy plan, incentives and disincentives, activities for direct federal support, choice of performers, and finally government-industry working relationships.

Need for a Total Plan.

In the long run, the development of new energy technology and its subsequent commercialization are essential for the nation to meet whatever goals for economic growth are deemed desirable. However, the objectives of an energy technology plan must be developed within the framework of a coherent national energy policy. Hopefully, we are finally in the process of developing this policy. No successful corporation develops an R&D or technology plan before it has thought through and agreed to a business plan which the R&D is intended to support. Government is recognizing this need and is beginning to give this problem greater attention.

Incentives and Disincentives.

Today, there are a number of economic, regulatory, and environmental barriers that are seriously impeding the capability of private industry to apply known technology and to develop new energy technology. There are artificial price constraints on oil and natural gas, constantly changing regulations and legislation, regulatory and environmental delays, and proposals to dismember major oil companies or prevent them from contributing to progress in other energy forms. These and other economic and political uncertainties combine to create a highly uncertain business climate for private investments in research and development.

These barriers are serious. They distort natural "market pull." They discourage industry from doing energy R&D that it otherwise would do, and they mean that industry will not commercialize many of the products of government R&D programs, that is, many processes and products that could be very useful to the country will not be brought to the marketplace under present conditions, independent of who pays for the R&D.

In turn, there are proposals to compensate for these distortions by government subsidy of R&D and a band-aid patchwork of government incentives for demonstration and commercialization. It is urgent and critical for government to do some "zero-base" thinking about these problems and seriously consider the possibility for some relatively fundamental changes. As an example of a case where a government is providing incentives and working with industry to develop an energy resource, there is the Athabasca Heavy Oil Sands Project in Canada. This $2.6 billion project is designed to produce 125,000 BBLS./day of synthetic

crude. The first train starts up in mid-1978. The Canadians established that Athabasca synthetic crude can be priced at parity with world crude; they have provided significant and rapid tax writeoffs; they have set clear, certain environmental requirements; and finally they have created a more favorable business climate for resource development. If those circumstances existed in the United States, there would be an entirely different industrial attitude toward a variety of projects, including shale oil and coal synthetics research, development and demonstration.

Activities for Direct Federal Support.

The government has a major problem in selecting which R&D projects it should directly support. I have found virtually unanimous agreement that it should provide significant funding for the long-term, high-cost, high-risk programs from which critical results are needed sooner than normal industrial efforts might provide. These programs include the obvious, such as fusion, solar and breeders, and they also include some that are not so obvious such as synthetic liquids from coal which industry cannot speedily develop on its own in part because of the current uncertain regulatory climate.

Another area for major government funding is basic energy sciences research. It is clear that industry does not and usually cannot afford to invest heavily in relatively basic research. This is because the benefits of such research are usually not fully perceived when the research is undertaken, because this research is high-risk from a return-on-investment point of view and because returns are not likely to flow only to the corporate funder.

Many companies feel very strongly that the government should not fund R&D in those areas that are being adequately pursued by the private sector. This is an extremely important point, which is directly related to maintenance of free enterprise. There is a significant problem for the government to learn what industry is doing or has done and to do this without leakage of proprietary information. Here, it would seem advisable for the government to establish a confidential procedure to seek advice from industry on which of ERDA's programs could result in unreasonable duplication of industry effort.

Choice of Performers.

Turning to the question of who should perform R&D, we must consider four major categories of energy research organizations: the universities, the contract research organizations, the federally-funded research and development laboratories, and private industry. Each has its own set of advantages and dis-

advantages that recommend it for performance in certain areas of endeavor.

First the universities. The primary missions of universities and colleges are in teaching, training, and the search for new knowledge. In research, they have the advantages of autonomy of project selection, independence, low institutional bias, credibility, some interest in interdisciplinary programs, and a broad dissemination of their output.

Federal R&D obligations to universitites and colleges for fiscal year 1977 total 2.6 billion dollars. But ERDA support is in fourth place representing only 6 percent after HEW, NSF, and DOD. Considering that the energy problem will be with us for a long time requiring trained manpower in a number of science and non-science fields, and considering all of the intellectual resources that academia can provide, there is a real question whether the government is providing adequate support for university energy R&D. In addition to research in the fields of science and engineering, some universities are embarked on interdisciplinary energy policy studies. This is very useful because there is a growing need to couple good science and engineering with good policy analysis. Some universities have the talent and skills in a number of interrelated areas such as law, medicine, the sciences, engineering, business, sociology and economics to make meaningful and much needed contributions. The independence of view and the commitment to intellectual pursuits coupled with their regional or local expertise qualify the universities to provide a unique, credible and valuable output. Industry is contributing to such university work with money and with information on the economic and technical limitations and opportunities for fundamental work. Such policy programs have broad appeal to faculty and students who have become more interested in social problems related to technology.

Contract research organizations have a special role to play in energy R&D. They have specialized expertise, a low bias and internal flexibility in pursuing contract objectives. They have made and can continue to make useful contributions in policy analysis, special surveys, and program management matters. They have the ability to perform in areas involving overlap and interaction among government, industry, and university people, since many are generally well respected. On the other hand, they have no stake in commercialization and should not become heavily involved in that aspect.

Turning to the federal laboratories and research centers, ERDA is responsible for 39 laboratories and 16 nuclear weapons and nuclear materials processing plants. Recently, some have diversified into solar energy, coal combustion, coal liquefaction and gasification, MHD, hydrogen production and storage,

battery research, geothermal energy, energy systems analysis, recovery of oil from shale, conservation, stack gas cleanup, and drilling. It is imperative that these laboratories develop close ties with industry so that the fruits of the laboratories' efforts are efficiently transferred on a timely basis. In addition, the laboratories must resist the temptation to go it alone or to hold on too long.

In view of the well known difficulty of transferring technology from the laboratory to commercial reality, it is preferable to maxamize commercially oriented R&D in industry laboratories. The government laboratories should do those useful and essential things which industry cannot do adequately, such as large scale basic science and basic engineering that universities cannot do and building of special facilities that are to be used by several organizations.

U.S. industry has substantial capabilities. It offers a large source of technically trained and experienced manpower responsive to market incentives. It has an extensive knowledge pool that integrates technical, financial, production and marketing skills. It has developed management methods for developing, financing, and putting in place "large" energy technology projects. Given adequate economic motivation, private industry can conduct commercially motivated energy R&D in the most effective way. Privately funded research must not only stand up to critical economic assessments, but it is carried out in a highly competitive environment in which technology development efforts benefit from continuing interaction with business management and the results of competition. Privately funded research is much more readily transferred into commercial practice than government funded research at other institutions.

I am pleased that ERDA has rapidly expanded its support of industrial energy R&D, but there is no room for complacency since the government does not yet know how to optimally work with industry to commercialize new techniques.

Government-Industry Working Relationships.

Finally, there is the question of how government can best work with industry to get necessary government funded R&D done most effectively. One of the best examples of government industry cooperation on government supported R&D was during World War II. At that time the government played the role of a supportive partner by setting clear objectives, making essential resources available, and avoiding micromanagement. Incentives to succeed were high and industry was largely responsible for determining how to do the job and then doing it.

The country is not yet panicked enough to reinvoke that mode of operation again. What we have evolved is some rather detailed, often inflexible, and usually time consuming R&D contracting processes. As a result, we waste a fair amount of time and R&D output suffers. A very encouraging recent sign is ERDA's development of cooperative agreements, wherein a significant amount of flexibility is possible.

There is no question that the government is responsible to the people -- that includes you and me -- for effective use of our tax dollars. On the other hand, many feel that the cost-benefit of present approaches is not as high as it could be. Some "ground-up" rethinking could yield some dramatic improvements and efficiencies.

The Government Does Not Agree

That completes what I wanted to say regarding an industrial view of the institutional aspects of energy R&D. Before leaving this subject, I would have to point out that the government does not seem to agree with a number of the key points that I have just tried to make. In the latest version of the ERDA budget, support for the high-risk, long-term inexhaustible technologies (solar, fusion and breeders) is held very near last year's levels. Basic energy science research is to receive only a modest increase and the government is dramatically scaling up its support for a number of the so-called conservaition technologies that have been the traditional responsibility of industry. Also there is no sign that university energy R&D is in for any kind of significant increase.

Recommendations

There are clearly some very difficult issues involved in energy policy in general and energy R&D in particular. It is unlikely that anyone will take action based on what I have just said; if they did, it would be some kind of a first. So let me make a very specific, double recommendation to ERDA (or DOE) and the OMB. The President has said that he strongly subscribes to zero-based budgeting. My recommendation is simply for ERDA (or DOE) and OMB to seriously apply zero-based budgeting and some "zero-based thinking" to the FY 1979 energy R&D budgets for the near and mid-term technologies. I urge that the tradeoffs between direct federal R&D support and alternative commercial incentives such as changes in regulations, pricing policies, and tax policies be seriously considered. I suggest that this exercise be started in government and then be opened for industry comment prior to decision. In a number of near-term technologies I believe that the government might better serve the national interest with smaller federal energy R&D budgets in conjunction with greater industrial stimulation.

Summary and Conclusions

In summary, I have tried to approach the energy R&D problem from a somewhat different point of view to help you to better understand at least some of the underlying issues. I also presented a widespread industrial point of view on energy R&D. My recommendation to resolve some of the outstanding conflicts in energy R&D is something that is clearly doable, and I believe would be extremely beneficial, if seriously undertaken.

The energy problem is to me the most severe peacetime threat the country has ever faced and so I am hopeful that we can rapidly evolve an effective energy R&D approach. We have an excellent start, but we may not have all that much time to optimize.

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R&D BUDGETS AND FUTURE OUTLOOK

Moderator: William D. McElroy, *(Chancellor, University of California, San Diego, and Chairman, AAAS Board of Directors)*

Panelists: John Stewart, *(Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate)*

Hugh F. Loweth, *(Deputy Associate Director, Science and Energy Technology, Office of Management and Budget)*

Philip M. Smith, *(Assistant Director for Natural Resources and Commercial Services, Office of Science and Technology Policy)*

Merwyn C. Greer, *(Controller, Energy Research and Development Administration)*

Robert L. Stern, *(Director, Business/Government Relations Research, The Conference Board)*

T. Dixon Long, *(Provost, Western Reserve College, Case Western Reserve University, and Member, AAAS Committee on Science and Public Policy)*

Panel Session Summary

R&D Budgets and Future Outlook

Topics addressed during the session included:

- *The problem of decreased funding to academic institutions for R&D.*
- *The differences in the incentive systems for R&D in industry and in academia.*
- *The effects of Zero Based Budgeting (ZBB) on R&D, in general, and on basic research in particular.*
- *The outlook for energy R&D.*
- *The status and outlook for R&D in industry.*

Introduction

William McElroy opened the first panel session by noting several issues in the commentary by Mr. Shapley and others on the R&D budgets for fiscal year 1978 that seemed critical for policy consideration in the 1979 budget cycle. He made a few observations on important policy issues that, depending on the decision, will influence the health and the future of our basic research activities in both our major universities and research-oriented industries.

The first issue discussed was the fiscal health of the leading research universities. Because so much of this nation's research takes place in a university setting, the health of American science is inextricably intertwined with the health of its universities. If our universities are of high quality, so too will be our basic research. Unless the core arts and science departments of a university are strong, its professional schools will inevitably be weakened. Dr. McElroy realized that the problems of a research university are varied and complex, but he was completely convinced that more adequate federal formula grants would be at least one very positive factor in maintaining university integrity and solvency. The National Science Foundation has lost its

formula grant program, and once again one was not included in the NIH budget. The universities are unanimous in their support of this type of funding, and it's difficult to understand why the last three administrations have failed to respond to this type of support. Needed renovation funds, the underpinning of research services and equipment replacement, are beginning to take their toll and something must be done to reverse this trend. Smith and Karlesky in their recent report highlighted these needs and left no doubt that this is one of the major policy issues facing the nation in its support and maintenance of the research enterprise.

Other forms of support which would give the universities some degree of flexibility to respond rapidly to research opportunities should be considered. For example, departmental or coherent area grants have proven to be unusually productive and consideration should be given to reinstate them at a significant level.

The relationship between the universities and the federal government has deteriorated to a point that it is having a major impact on our research effort. Disagreement on the overhead and stricter auditing procedures have not been fruitful and have cost the universities funds and time which could more profitably be spent on research. These items should be resolved once and for all if we are to move ahead in a cooperative and fruitful manner.

A second major policy issue mentioned by Dr. McElroy concerned the support of the young investigator. As we come into a steady state enrollment in our major colleges and universities, it is evident, at least for a decade or so, that there will be reduced opportunities for employment of young investigators. This is bound to have a major impact on our research establishment. The federal government should provide funds to support the best young academic researchers for the first few years until they have provided a record which can be judged by their peers for support through the regular mechanisms. In addition to the support of these independent investigators, the postdoctoral support program should be reinstituted at a significant level of funding.

A third major policy issue discussed concerns the mechanism of funding and managing multi-disciplinary, problem-oriented research. We need to find an appropriate environment which will accept, support, and reward members of the scientific community whose contributions are in the less traditional vein. If we are to meet the major challenges of our country and the world, we must do research that is focussed on solutions to problems and make sure that they are well-organized and sensitively managed. Dr. McElroy believes that a new kind of research enterprise is likely to emerge in the coming age:

large-scale operations designed to grapple with problem-focussed rather than discipline-focussed issues. We have had some experience on how to mobilize and manage such enterprises, but we need to do more. Some aspects of problem-oriented research will best be handled by universities, others by federal or federally-supported laboratories, and others by industry. Wherever the action may be, we will need to develop more sophisticated classifications of problems, especially in the area of what is short term and what is long term, and have the capability to assign the most effective institutions to the appropriate tasks. He suggested that the best way to orchestrate such undertakings would be through lead institutions or consortia of institutions which would assume the responsibility for research and development on a manageable segment of a societal problem. The consortia or lead institutions would not monopolize research efforts in a specialty but would foster coordination of research efforts throughout the country. There are a number of problems associated with this concept, but we must get away from a piecemeal approach to some of these major problems if we are to move ahead. Dr. McElroy concluded by saying that he could not think of a greater science policy issue for the academic and government communities to consider during the next few years.

Prepared Presentations

John Stewart began his talk by stating that since he was new to the area of R&D, he would not try to identify substantive areas. Others on the panel could do that with greater insight. He would focus on the process by which substantive areas get considered and acted upon. Congress is not a hierarchical body. Each member thinks he got there on his own efforts. Although the OMB, in order of speakers on this panel, has the last word within the Executive Branch, this is not the case in Congress.

Comments made at the morning session indicated that President Carter is concerned with the broad picture of R&D. A broad strategy for R&D is what is needed. Furthermore, Carter's pledge for a balanced budget by 1981 is going to figure in this broad picture. The level of economic growth which the United States is able to sustain is a factor which will affect a balanced budget and the size of the federal revenues available. Zero Based Budgeting is a new process which will also have an effect on R&D budgeting. The Office of Science and Technology Policy (OSTP) is still another influence on R&D policy. Supporters of OSTP hope that the reorganization plan which is currently being designed will

leave the OSTP intact.* If not, the voice for a rational and balanced R&D policy will be left weaker.

Dr. Stewart reminded the audience that OSTP has several responsibilities mandated in the Science and Technology Policy Act. One task is the preparation of a two-year survey which will look at all aspects of science and technology policy including R&D, analyze the situation, and make recommendations. However, the status of the survey is in doubt, as is the future existence of the committee that was commissioned to conduct the survey. This survey would be of help to Congress in its action and planning for R&D. The extent to which the results of the survey are made available to the Congress will determine the difficulty in getting funds for R&D. The way will be made somewhat easier if Congress is permitted to participate.

OSTP also has the responsibility of preparing a five-year outlook on science and policy areas in an attempt to identify problems as early as possible in order to correct them. The scope of this five-year outlook is being examined by two outside contract research firms whose task is to identify the problems and set forth procedures for solving them. Hopefully, the firms will act quickly so the five-year outlook can go forward. These two studies will lead in the direction of a more disciplined process for developing the R&D budgets. Congress will have a role in determining broad policy, and not just in deciding line items. The more interchange, the more rational will be the process. If the opportunity for communication is not taken, the potential for nit-picking and second-guessing will increase.

Another important effort that should also be helpful to Congress is the study of R&D priorities and policies being done by the Office of Technology Assessment (OTA). This study gives Congress the kinds of insight helpful in the process of R&D budget making.

Dr. Stewart concluded his presentation by saying that this is a time of change and newness--a time of beginning. There is still the opportunity to make decisions, to bring the Executive Branch and the Congress into more responsible and productive dialogue. A sensible, balanced, and productive R&D budget is very likely to be one of the results.

In his introductory comments, Philip Smith focused on Willis Shapley's work. Shapley has put together a report

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* The reorganization plan for the White House was sent to Congress on 15 July 1977.

concerning budget decision processes which we must focus on in this era of constrained budgets. As Mr. Cutter pointed out, R&D is one of the few budget items that is controllable.

All the people in the Executive Office of the President are sensitive to the importance of R&D. The issue is not whether R&D should be supported. This is understood. However, there are honest differences of opinion about the approach which should be taken; for example, whether money available should be used for the support of R&D or for formula grants to institutions. Regarding the questions of research related to regulatory processes and regulatory agencies, Smith said we must make comparisons and set priorities. Some increases for research related to the regulatory processes may be in order, but this might be accompanied by offsetting reductions in other mission oriented research support.

Willis Shapley has raised ideas that should be looked at seriously by all people concerned with support for sciences--by people like himself. Discussions about different strategies for looking at R&D should not only come from the top down, but should be given priority within agencies by people in the field who are closer to the problems.

Mr. Smith stated that we should try to make Zero Based Budgeting work; however, he is skeptical about its application in the area of basic research. There may be process oriented machinery put together which could churn up a great deal of information that might not help in working out priorities or in deciding which areas of basic research should be supported.

We should give serious consideration also to the concept of the "Baseline Planning Envelope" described in Willis Shapley's book. And going even one step further, we could begin to think about the R&D activity of the government more as a standing account, looking at the interrelations of the enterprise rather than looking at it agency by agency. If certain kinds of research did not seem productive, there could be transference of money within the account--not only up and down within an agency, but between agencies. For example, money for environmental research could be transferred from NSF to EPA, or from law enforcement R&D activities into basic research. Three billion dollars has been budgeted for basic research, half of which goes to two agencies--NSF and NIH. We could use this interagency transfer approach to help solve the problem of support for young scientists mentioned by Dr. McElroy. In this situation, relatively small amounts of money and relatively small adjustments could make a big difference. OSTP is concerned with the transfer of research funds between agencies.

Another area of concern to the OSTP is the status of R&D

in industry and the interrelationship between government sponsored research and industrial research. There have been some signs in industry of greater commitment to short-term activity than to long-term projects. We need to know whether increased regulatory activity is adversely impacting the research scene or is in some cases bringing forward new technology. A better understanding of the relationships between government and industry and of decision processes in industry is very important to OSTP in its deliberations on R&D policy.

Merwyn Greer focussed on R&D in the area of energy. ERDA has a large energy R&D program that has nearly tripled since 1975. ERDA's basic science program has not fared quite so well though it has shown some growth over the past 3 years. There is also the mission directed R&D program, in weapons and naval reactors, and in space technology. Energy R&D is an unusual type of activity for the federal government because basically it involves developing technologies that can be turned over to industry for commercial application. It is a sophisticated R&D field because it involves interaction of R&D with incentive schemes and other means of initiating technical activity. The line separating the commercialization from the demonstration phase has been rather difficult to define. Indeed, as the Department of Energy is about to be created, an area of major concern is the federal role in relation to R&D programs and other incentive programs.

The economic effect of higher energy prices will be of primary importance in the short run. There will be more emphasis on incentives to develop independent energy capability in order to avoid the disruptive effect of increased prices. For the mid-term there is tremendous Congressional interest in what can be done to provide energy substitutes. There will probably be an acceleration of R&D efforts in areas with well defined benefits where it will be possible to enter the market at prices close to world energy prices. There will be pressure on longer-term efforts--for example, solar electric, breeder, and fusion programs. These programs have had a large percentage of R&D dollars in the past. If they continued at the 1977 rate, they would essentially dominate the budget over the next few years. Mr. Greer looks for constraints on the R&D budget with economics playing an important role in applied R&D efforts.

Moving briefly to the basic sciences area, Mr. Greer reported that the programs in ERDA are sound and reasonably well funded, although no significant growth is expected. The high energy physics program has been moving forward at an even pace from year to year. Natural sciences will probably be better supported than they have been in the past. The material sciences

have good prospects. There will be strong pressures to look for offsetting ways to fund the programs. Zero Based Budgeting does introduce a new element in funding for basic research. For example, it is hard to equate the benefits of post doctoral training with the same types of quantitative benefits that one can assign to relatively near-term R&D efforts, but ways of measuring the benefits and stating objectives and output can be designed.

In concluding, Mr. Greer said what he would like to see from the scientific community is an explanation of the benefits that would come from an R&D effort and a better awareness of the applications of basic research in the solution of the energy problem.

Hugh Loweth would like to hear more analysis and less emotion from the scientific community. Four million dollars in formula grants and more post-doctoral positions will not solve the problem of financial support for young researchers unless we also have more long-term employment opportunities for them.

We should avoid technology for technology's sake. For example, we know how to build a nuclear powered whaling ship, but who needs it? That is quite different from basic science. Basic science goes beyond particular problems. The key to federal investment in R&D is to ask what are we going to get out of it, and are we doing what is appropriate for the federal role? Looking back, it seems that some people were more concerned about the capability of landing in the Marianas Trench than with what we would do with the capabilty that was achieved. We should ask more questions in advance of what we do. "Capability" was what was important in the initial space drive. Now people are asking, for example, "Is there a need for a permanent space station, even though we can do it?"

There is a special problem in the area of civilian R&D where the government is not the consumer. The federal government has embarked in many so called civilian areas of R&D such as transportation, but ERDA is the biggest "civilian" investment. The future of ERDA depends on many constraints and uncertainties. There is a need to give the private sector a better and firmer idea of what the future will look like in terms of regulatory constraints concerning the environment so they will know whether it will profit them to proceed. In civilian R&D where the government is not the user, there is a danger in coming up with white or grey elephants that might not be needed until some time in the distant future. ERDA has been doing more about better timing of new technologies entering the commercial sector.

Mr. Loweth worries about the tendency of some members

of Congress and of some parts of the scientific and technical community to view R&D as a way out of the energy problem, and the tendency to say, "Well, if we just invest a lot more money into solar energy research we can solve that problem." In the case of solar research, we cannot just assume that the availability of technology means that it will find a rightful niche. Even though we are obviously moving toward higher prices when it comes to energy, we don't want to go to an exceedingly high priced economy which will put us at a disadvantage in the world economy.

Robert Stern began his talk by complimenting the AAAS for the effort over the past two years to clarify the federal processes involved in R&D budget making. Testimonies to the success of the effort are first, the audience is twice as large this year as last, and second, the percentage of participants representing industry has risen from 5% to 20%. The rest of the audience is evenly divided, with 40% from government and 40% from academic and non-profit institutions. Hopefully, in the future there will be roughly equal representation from each of the three sectors.

In the Smith and Karlesky study on academic science, concern about vital signs was voiced. Stern was concerned about the vital signs of industrial R&D. Participants have commented that they don't know enough about industrial R&D budget decision-making. This would be easy to find out. We have ready access to the industrial community, especially through the Industrial Research Institute. We should talk not only to R&D management, but also to top corporate management who are the ones that make the final decisions. There is an OMB in every corporation. R&D decisions are not made so differently in industry than within the federal government. R&D is one of the few controllable expenses for industry, too.

Seventy percent of the R&D done in the U.S. is performed in industry. This means that of the United States budget of $43 billion for R&D in 1977, $30 billion will be spent by industry. Comparing the total U.S. expenditures for R&D over the last 15 years in constant 1972 dollars, we find that the level of support in 1977 is equivalent to $30 billion, which is the same as the constant dollar level in 1965 and only $5 billion greater than that in 1960. On graphs, the United States expenditure for R&D looks very good. However, today we are doing only 20% more R&D as measured in constant dollars than we were doing in 1960. In constant 1972 dollars, the $30 billion that industry budgeted for R&D in 1977 is equivalent to $21 billion, which is slightly less than the constant dollar level of $22 billon in 1968. Colleges and universities are doing $5.3 billion today. In constant dollars, this is $3.8 billion, compared to a constant dollar level of $3.5 billion in 1968. Therefore, basically, we can say that the

level of R&D has been held constant while the rest of the economy has risen.

It is a myth that most of the R&D of industry is supported by the federal government. Statistics tell us that now 62% of the funds used by industry for R&D are provided by the corporation and only 38% are provided by the federal government; this is down from the 54% that was provided in 1960. The federal share of the funds is going down and industry's share is going up. On the whole, we are about where we were in 1965 and 1968. If we take out 2 industries--electrical machinery and aerospace--we find that they account for 50% of the federal R&D budget of industry. Aerospace is 80% federally supported and electrical machinery is 50% supported by the government. The R&D for the rest of the economy is approximately 15% supported by government and 85% supported by corporate funds. Thus, the American economy as a whole is operating fairly independent of federal funds. However, in no sense is it really independent. Domestic industrial R&D goals are heavily affected by pollution requirements, tax treatment of R&D, international foreign source income, and new requirements regarding energy utilization and conservation.

For 15 years McGraw-Hill has published a survey of business plans for R&D. It is a survey which cuts broadly across manufacturing and non-manufacturing industries. A distressing statistic in the current survey is that in 1977 we have reached the lowest point in the 15 years of the survey in terms of industry's prediction of the percentage of products that will come as new products three years hence. It is estimated that in 1980, only 13% of the sales will come from products not on the market in 1976. The average over the last 15 years has been 17-18% with a high of 19% in 1970. This indicates that industry is pessimistic. Where are the allocations of R&D resources going? Sixty percent of R&D resources are going toward improving existing products. The electronics and electrical machinery industry estimates that by 1980 only 11% of the products will be new, and it is estimated that overall only 28% of R&D will be invested in new products. This is a new low.

When industry considers a long-term investment in R&D, say in an area such as energy, the lurking possibility of government funding can cause industry to stop all action in that area. Industry asks, "Why should we use our own money?" The reasons industry underinvests in such a situation is the uncertainty and delays involved.

When we come to look at industrial R&D budget making processes in the AAAS report, we find only four pages devoted to this aspect of R&D. Section P, the Industrial Science

Section of AAAS, is proposing to be the godfather to a study on what is happening in the industrial R&D picture.

The AAAS includes the term "advancement of science" in its title. Hopefully, it will take its own name literally. Today we are talking about R&D. R&D is not exactly the equivalent of science. R&D is usually measured in terms of dollar input. Very few people talk about output. The output tends to be advancement of science or technology. Most of the analysis that is done in the budget making process talks about the input. What are we getting out of the billions of dollars of input? And how productive is the process? How productive are we comparatively across sectors within the United States and between ourselves and the rest of the world? It would be useful for AAAS to attempt to measure output as a complement to its work on input.

T. Dixon Long* stated two premises that he would examine with respect to their long-term implications for academic research. First, the leveling off of funding for basic and developmental work can be taken as a fairly long-term phenomenon, at least as measured by its relation to overall governmental spending or national product. Second, the conduct or support of basic and developmental science and technology has been diffused throughout the departments and agencies of the federal government, and now there seems to be a slow but steady extension of the phenomenon to state and municipal governments.

Dr. Long began by offering some simplifications about how the government sector now functions, and then moved to the academic enterprise.

First, since science and technology are being supported to achieve objectives defined by government, almost all government funding is or will soon be what we call mission-oriented. There is nothing very surprising about this. It is probably a contradiction to expect the National Science Foundation to fund research in the same way a bench chemist proceeds toward discovery. The experience of the Office of Naval Research and the wartime activities of OSRD may be misleading, for the fact is that as R&D has become more important it has also become more serious. It has to be accountable and it has to show results. Second, the great surge of effort from 1940 to 1970, in which the bulk of funds were channeled through a defense-oriented enterprise, has

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* Dr. Long could not attend the colloquium due to illness. This summary was adapted from his prepared remarks.

slackened and to some extent is being replaced by a new surge of effort directed toward health, energy, the environment, and a few other areas, all of which might be characterized as welfare-oriented in the broadest sense. There is a substantial change as well in the socio-economic structure of the research enterprise, though we will continue to see a large volume of defense R&D on the scene for a long time to come. However, it is likely to be less dominant. Third, all of this mission-oriented R&D in so many departments and agencies of government implies and, indeed, requires the existence of a whole new cadre of R&D managers who provide the basis for a more rational system of oversight and control. These managers effectively complete the bureaucratization of the federal effort in support of science and technology.

Academic institutions have been changing, too. Superficially, there was disenchantment and even revulsion against government-sponsored research im the late 1960's and early 1970's, but there was also a deeper problem of adjustment to the changing priorities and procedures of funding agencies. Simultaneously, there has been and still is a staggering cost-crunch as enrollments in private education have levelled off and the costs of providing educational services have climbed. In the midst of all this, we have rediscovered the importance of teaching, and realize that it is dangerous to pursue research activities without having some real concern for their educational purposes.

In Dr. Long's view, the government and university sectors have been moving in divergent, if not opposite directions. If there is a need and an obligation for the federal government to support academic science, then this divergent trend will have to be recognized and some measures introduced to alter it. Government has established a "broker" relationship among universities, itself, and other actors. Government deals with universities through grants and receives R&D results. It deals with business and industry through contracts and receives R&D services. Generally, it has functioned to channel or "broker" the management of results and services among itself, universities, and industry through the grant-contract system. The difficulty with this system is that it creates dependencies which suffer when support is withdrawn or altered. Furthermore, it has brought us to believe that the academic and business enterprise sectors are and ought to be insulated from each other with respect to R&D activity.

Dr. Long proposed an alternative model that is consistent with his description of a mission-oriented, highly diffused, and bureaucratized federal R&D establishment, whose support of research is broadening well beyond defense-oriented activities. He characterized his model as the "manager" as opposed to the "broker" relationship. The government still needs to provide

funds for grants and to negotiate contracts for research and development, but it increasingly needs a capacity to balance the system while standing apart from it. Mission agencies will continue much as in the past, with the addition of new and different missions, but several functions that are presently unmanaged could be addressed in a more coherent and self-conscious fashion.

First, the relationship with business enterprise is becoming that of establishing and enforcing standards and practices, a job carried out with extremely varied results as one looks across the spectrum from the design of space hardware to the control of pharmaceutical products. Second, the exchange of research sponsorship and R&D results directly between universities and business enterprise has been poorly articulated, principally because it has been conceived as a need for specific innovations or a class of innovations rather than management of a process. Third, support for basic research in the universities has been brokered rather than managed with results that are amply documented in the Smith and Karlesky study on The State of Academic Science, resulting in overconcentration in a few institutions and emphasis on short-term objectives.

Dr. Long concluded with a suggestion regarding the management of the government's relations with universities. What is needed is an endowment approach in place of a project and program approach. This concept is suggested by the titles of the National Endowments for the Humanities and the Arts, but they may be behaving more like foundations in practice. There should be open-ended grants of institutional support for a number of universities, say fifty, each of which would undertake to focus its activities in a few areas of basic research. This does not imply that the government should diminish its appropriate concern with accountability and with results. It will be the job of university officials to persuade federal managers that the purposes of the endowment are, in fact, being served. This suggestion is really not very different from the concept under which support for federal contract laboratories and research facilities is currently administered. However, it would be vital to recognize the differences between annual funding for specific missions and long-term funding for a balanced national capability in fundamental research.

Discussion

The topic of formula grants to academic institutions raised by Dr. McElroy in his speech was referred to several times. Proponents of formula grants emphasized that such grants allow universities to support young researchers and to

respond to needs with flexibility. Mr. Loweth commented that NSF has moved a step away in recent years from justifying the support of basic science as a means of supporting graduate education. The tendency now is to focus on what needs to be done in order to advance basic science and simultaneously to deal, where possible, with critical problems either in an agency context or in a national needs context. He stressed that the key question is what needs to be done to make sure we have viable, high quality institutions in which high quality research will be conducted and not how much money should be awarded to institutions qua institutions.

The problem of accountability was raised relative to institutional grants, and opposing views were offered. Using as an example NIH Biomedical Support Grants, Mr. Smith said that an examination of institutions to determine the differences that the money had made in their programs produced disappointing results. It was hard to obtain information supporting the effectiveness of this kind of grant mechanism. Dr. McElroy retorted that there was a fundamental disagreement on this issue. He had been on a committee to find out how institutions had spent their formula grants. The data indicated that 65% of the money had gone to young investigators and 25% had gone for equipment, especially equipment for young investigators. Dr. Hirsch mentioned that corporations feel that the situation in universities is not good; that universities and industries have gotten decoupled. To try to remedy this situation, Exxon has provided institutional grants to universities. He has learned that the funds are being used extremely well. People are not taking advantage of the situation, but are policing themselves. Money is being handed out very carefully and accountability is required. The universities are doing this for grants that had no strings attached. While the federal government should require some accountability, it still has the responsibility to support basic research.

Similarities and differences between R&D in industry and in academic institutions were highlighted. Several references were made to Mr. Stern's comment that the prospect of the government's injecting federal funds into an area of research caused industry to back off from R&D in that area. Mr. Stern explained that the money that industry would be investing is its own money. This is real risk money. Universities are great sinks for money. They don't have to produce a profit. All they have to do is get the contract out. The sets of incentives are completely different.

A participant from industry emphasized that any industry does R&D for a particular business purpose--to maintain and expand business in existing areas and to enter new areas. He commented that industry was moving more and more toward

maintaining and extending its present business. Industry can't afford to move into areas that are not commercially profitable. If R&D in a specific area isn't relevant, it becomes a controllable item and it disappears from the budget. It was mentioned that the cost-sharing experiences of ERDA with industries were examples of programs that successfully involved the cooperation of government and industry.

One participant commented that he didn't see as much discrepancy between the plight of universities and industry as had been expressed at this meeting. He proposed that more federal R&D funds be directed away from universities toward industry on a cost-sharing basis. At the same time, we should investigate the mechanism by which some of the exploratory development could be done by universities on behalf of industry. This would be a way to bring universities and industry together. It would help industry get innovative ideas, help universities have a more stable source of funds, and provide a connection between student training and potential employment opportunities.

A comment was made that 30% of the profits from R&D were from outside the U.S. However, exports are growing most rapidly in our most advanced technological areas. In stable industries exports are dropping off. Therefore, if we really want to solve the balance of payments problem and increase our standard of living, now is the time to increase R&DS in basic science. In terms of innovation, the U.S. is far ahead of anyone else, but we have to become technologically intensive. The Japanese have shown that they can take our past accomplishments and beat us at our own game. We should intensify the support of basic science and intensify R&D even beyond the present level.

Mr. Carey commented that the Executive Branch of the government is seriously committed to Zero Based Budgeting (ZBB) which includes programming for R&D expenditures as well as for everything else. He questioned whether the Congress, the other half of the action for determining the outcome for work in R&D, is ready to do business in terms of a ZBB approach to decision-making. If the decision flow from the President to Congress is keyed to ZBB and the Congress is wedded to a view of incremental budget decision-making with its own view and constraints, there might be quite a problem facing us. Is anything being done to bring the two branches together? Is there any useful role that the AAAS can play in trying to convene the parties on neutral ground to look at the implications, advantages, and problems of ZBB as R&D is affected?

In response to this question, Dr. Stewart stressed that it will be very important to include Congress at every step of the way in order to keep the members of Congress informed. He

mentioned that there are mechanisms already established in the Science Policy Act to respond to ZBB, and that they should be utilized. Another participant emphasized that ZBB had been designed for managers not for legislators. Congress would only be able to examine a few programs in the detail required in ZBB exercises.

Several questions that were raised concerned basic research. One participant proposed that the term basic research be defined. The comments that followed demonstrated that there is a spectrum of meanings for this term and for the term applied research. Respondents suggested that the difference between these two terms lies mainly in the perspective of the researcher. Concern was voiced about the future of basic research under Zero Based Budgeting (ZBB). Questions were asked about the criteria that would be used for selecting basic research projects. One participant stated that the criteria would be the same as they are now--that the research be high quality and significant. ZBB will be of no greater threat to basic research than any other process where research programs have to compete for funding. Fear was expressed that under ZBB funding for basic research projects would be discontinued after two or three years. The need for continuity in basic research was emphasized.

Dinner Address

Adlai E. Stevenson
United States Senate

Senator Stevenson was elected to the U.S. Senate in 1970 to serve the unexpired term of the late Senator Everett M. Dirksen and was reelected in 1974. He is Chairman of the Subcommittee on International Finance of the Banking, Housing and Urban Affairs Committee; Chairman of the Select Committee on Ethics; and serves on the Select Committee on Intelligence. Last year he served as Chairman of the Temporary Select Committee to Study Committees which led to the first reorganization of the Senate in 30 years. Most important in the context of this colloquium, he is now Chairman of the Subcommittee on Science, Technology and Space of the Commerce, Science and Transportation Committee.

Senator Stevenson graduated from Harvard College and Harvard Law School, and served in the U.S. Marine Corps. He served in the Illinois House of Representaitves and was elected State Treasurer in 1966.

It is a pleasure for me to participate in your second colloquium on research and development in the federal budget. The AAAS is to be commended for tackling such a formidable subject. In a sense, Congress avoided such a step until 1974 when it passed the Budget Control Act. I can, therefore, sympathize with your effort to understand one of mankind's most complicated and important documents.

Last year's colloquium was your first attempt to initiate the Association's members to the intricacies of the federal budget process. Willis Shapley's excellent study of the 1977 budget and his 1978 edition, just released, provide the basis for making a more accurate assessment of the R&D budget's impact on the nation's scientific and technological enterprise and our economy. I know these meetings will be productive and useful.

Having been actively involved in the world of science and technology for less than six months, I expect to carry away from this gathering far more than I contribute. I am told this process is known as "technology transfer" and I welcome it.

In exchange, I can only offer the first impressions of one whose record in science and technology policy is relatively clear of positions to defend or causes to advocate. I can't guarantee how long this state of innocence will continue, so I had better proceed.

As most of you are aware, the Senate earlier this year modified the number and jurisdictions of its standing committees. One important result was an expansion of the science and technology responsibilities of the Commerce Committee, now identified as the Committee on Commerce, Science and Transportation. A new Subcommittee on Science, Technology and Space, which I chair, was established to exercise this expanded science and technology jurisdiction.

We were given legislative jurisdiction over the National Aeronautics and Space Administration, the Office of Science and Technology Policy, and the science and technology activities of the Department of Commerce. We also have jurisdiction over all legislation affecting the National Academy of Sciences, the National Academy of Engineering, and the National Research Council. In addition, the Senate created the jurisdiction of "comprehensive policy oversight" and made the Committee responsible for science and technology, including all research and development activities of the federal government. Although the legislative mandate is not as broad as that of the House Science and Technology Committee, the combination of our legislative and comprehensive policy oversight responsibilities provides a solid base from which to observe and influence federal R&D activities.

The pervasiveness of R&D considerations in almost every Congressional decision is striking. This is true whether Congress is considering distinct federal R&D components, such as the NASA or NSF budgets, or developing policy that depends on the results of R&D efforts, such as energy policy or the Clean Air Amendments debated in the Senate last week.

Although the impact of R&D is pervasive, Congress as a whole finds it hard to examine R&D concerns in a sustained or systematic way. Attention is paid sporadically to large military or space R&D efforts in which major contractors have an interest. But more routine R&D items in legislation can slip through Congress almost unnoticed and unexamined. The Executive Branch is often as unfocussed as Congress.

A case-in-point is the pending reorganization of energy functions in a Department of Energy. The importance of R&D in accomplishing the Department's mission is obvious. An estimated 70 percent of its budget will be spent on various R&D pursuits. Yet, the Administration's initial legislation submitted to Congress provided no focal point for directing and coordinating R&D. Instead, the responsibility for R&D was dispersed among five Assistant Secretaries. Moreover, the relationships between basic and applied research and the development and demonstration of energy technology were unclear.

The Congressional committees and the press were principally concerned with the more politically volatile issue of energy

regulation. An effort to create an office or administration within the Department to supervise basic and applied research was dropped by the Senate committee. The R&D issue was discussed explicitly in one paragraph of the Senate committee report and in a brief colloquy on the Senate floor which I conducted with Senator Ribicoff. In essence, the Senate delegated to the Secretary of Energy full responsibility for devising a workable R&D structure.

The House committee approved a fragmented R&D structure similar to the one initially proposed by the Administration. However, the House during floor debate, did adopt an amendment by Representative Moss of California creating an Office of Energy Research, headed by a Director at the level of Under Secretary. The Office was given responsibility for coordinating all basic research activities within the Department and advising the Secretary on all other aspects of energy technology development and demonstration.

This action, in my opinion, was a distinct improvement over the structure initially proposed by the Administration and the one approved by the Senate. The issue now must be resolved by the conference committee.

This colloquium should focus on the reasons for this failure to develop an explicit R&D strategy for the Department of Energy. There is little evidence that the issue received much attention when the Administration was preparing its legislation. Even now, the Department of Energy Activation Task Force, chaired by former Air Force Secretary Thomas Reed, has no planning group assigned to the R&D issue, even though about a dozen such groups are in operation. This fact is particularly distressing since both the House and Senate bills place strong reliance on the Secretary of Energy to guide the R&D effort. Congress has been only a little more attentive to the energy R&D issue than the Administration. This experience with the Department of Energy legislation coincides with my broader impression that R&D policy for the federal government is too often the result of *ad hoc* decisions and short-run pressures. Those seeking federal funds for development or demonstration projects often behave in ways suitable to an Oriental bazaar. Advocates of basic research may be more restrained, but they also tend to lose out when funds are allocated. There is little agreement over the goals and priorities that should guide the Executive and Congress in drawing up the R&D budget.

As long as federal support for R&D was rising sharply in the early and mid-1960's, there were sufficient resources for all major segments of the R&D community. Many useful things were done in these years although difficult questions relating to the purposes of science and technology in achieving broad societal goals were often pushed aside.

As the federal budget squeeze grew severe in the 1970's, competition for R&D dollars became more spirited. The new stringency in federal R&D support produced a number of results:

1. R&D as a percentage of the federal budget has declined. The estimated Carter budget for fiscal year 1978 calls for R&D allocation of 5.7 percent, considerably below the 7.2 percent in FY 1972.

2. Estimated federal support for basic research in FY 1978 is less than 1967, using constant 1972 dollars. This is true even though the FY 1978 budget provided a proportionately larger increase for basic research. As Willis Shapley points out in his study, even in current dollars, funding for basic research in ERDA, NASA, and DOD declined from 1967 to 1975.

3. The future health of academic science has been threatened. In their recent study on The State of Academic Science, Professors Bruce Smith and Joseph Karlesky point to signs that threaten deterioration of American scientific research over time, even though the level of accomplishment today is outstanding. They note the trend toward a less speculative, risk-taking science and the gradual decline of scientific excellence in second-rank departments and universities. There is increasing concern over the decline in the number of talented students who select science as a career.

4. The emphasis on achieving concrete, short-term results has adversely affected the support of many projects that are not related to easily identified human problems. I think particularly of two NASA scientific projects, the Jupiter Orbiter Probe and the Space Telescope, which have encountered serious funding problems in this Congress. Both projects are within the Congressional budget targets; both have been authorized by the Senate and House; both are part of a carefully designed and thoroughly reviewed space sciences program adopted by the National Academy of Sciences.

   Our national priorities must have room for this kind of scientific investigation. We must be sufficiently farsighted to understand that greater knowledge of our planet and solar system and the galaxies beyond is bound to enlarge our understanding of the physical and biological forces that affect everything we do. We must also be wise enough to understand that the spirit of discovery is a unique human attribute that must be recognized and supported.

5. The politics of limited budgets also has led us into limited ways of thinking. Justifications for R&D programs were increasingly based on some favorable benefit-to-cost ratio. Though the benefit-to-cost approach can add some rationality to an R&D decisionmaking process, we must be aware of the limits of determining value in strictly economic terms. Economics is but one criterion upon which to base a value judgment.

At the same time that federal R&D budgets were being squeezed, two other factors came into play:

1. Unfamiliar voices of the public, outside of the professional scientific and technological community, began to analyze and question federal science and technology policy. These new voices reflected growing skepticism about the role of science and technology in society. Inevitably these public attitudes found expression in the decisions of Congress and other governmental bodies.

2. Congress itself became better able to examine and judge Executive budget proposals. Passage of the Budget Control Act of 1974 did more than provide Congress with a Senate and House Budget Committee and a Congressional Budget Office. It also signified a new Congressional determination to assert itself in the annual budget cycle in a more forceful manner.

As new uncertainty has intruded on the R&D funding process, the temptation has increased for individual sectors of the scientific and technology community to try to cut their own deals with the Administration and Congress. Although this concern for self-preservation is understandable, the consequences can be very damaging to the scientific and technological enterprise as a whole.

Those who organize direct appeals in behalf of a specific R&D endeavor may be successful in the short run. But they increase the danger that Congress will act irrationally when the volume of special appeals becomes too large to handle. A more orderly process reflecting some common agreement as to R&D priorities would be distinctly preferable.

I suspect that much of the uncertainty and unpredictability that now attends Congressional action on the federal R&D budget is an outgrowth of ambivalent public attitudes concerning the broader role of science and technology in government and society. One does not have to reel off a laundry list of unrealized expectations of the past 20 years to make this point: the benefits of science and technology were oversold during the 1950's and early 1960's and the costs of many such activities were either unrecognized or avoided.

The vision of a utopian society created by the miracles of science holds little credence today. In place of this vision, we must search for a new, more balanced, and mature perspective of science and technology that can serve both the Executive and Congress in deciding who should spend how much R&D money for what kinds of purposes.

I do not advocate some centrally designed and imposed R&D blueprint. A degree of decentralization in federal R&D funding is necessary, and competition for public funds, if conducted under proper rules, is healthy. But this activity should be guided by a more clearly defined sense of purpose and the capacity to make wise choices.

If these impressions are at all accurate, it is unlikely that a balanced and healthy R&D budget will result simply from more vigorous lobbying. The first and essential requirement will be to achieve public recognition of the legitimate role that science and technology can and must play in helping solve civilization's most urgent problems and in expanding knowledge of our world and universe. Achieving these mature perceptions is far more complicated and challenging than mastering the intricacies of the federal budget cycle.

This balanced perception of science and technology by the public, and the R&D budget strategy that hopefully would reflect this perception, must be the product of free inquiry involving all segments of the science and technology community, the Executive and Legislative Branches, and the public. No individual or professional society can provide all the answers. The process by which these new perceptions are developed will be extremely important.

Several factors would seem to deserve special attention.

More reliable quality control in evaluating and managing federal R&D efforts would help remove targets of Congressional and public skepticism. This objective is not easily achieved. However, as R&D efforts cross boundaries of traditional academic disciplines, I wonder if the practice of peer review based on the traditional disciplines is adequate in every case. Solicitation of additional points of view on the excellence and significance of an R&D proposal or project, according to orderly and agreed-upon principles, would seem to make sense.

Improved management of the federal government's R&D facilities is also important. This effort should be directed less at eliminating duplication of effort and more at focussing limited resources in support of truly significant research.

The federal government must be more careful in funding demonstration projects. We should have learned by now that

certain conditions are essential to success. These include a well-developed technology, a sharing of risk with other participants, local interest and initiative, and a well-developed plan for commercialization. Federal money, by itself, is not sufficient.

We must be willing to ask tough questions. Does federally supported R&D really expand industrial innovation and productivity? Should federal efforts be directed instead at creating R&D incentives in the private sector? What is the real public interest in federal R&D spending?

Furthermore, we need to find ways to support and test the ideas of individual inventors who attempt to translate scientific understanding into commercial innovations and applications. This is an age of big science and large technological systems driven by economic forces and large institutions, both private and public. Invention and wisdom is not the sole property of these institutions; large is not always best. We need to rediscover how the contributions of individual experimenters and entrepreneurs can be made available to society as a whole.

The public also expects a more forthright accounting of problems incurred through a growing dependence on technology. This involves more than preparing an environmental impact statement. For example, the Subcommittee on Science, Technology and Space is conducting hearings on legislation to establish a national climate research program. Witnesses have emphasized how our present weather problems are not beyond the range of climatic conditions likely to occur over the course of several decades. Crises stemming from drought or the severe cold of last winter are more the result of a technologically dependent society that exists on the margins of what our natural climatic system can be expected to support. Now that we are entering a period of below-average precipitation, there is almost no margin or flexibility for safety.

Forthright public accounting places on science and technology an obligation to alert society to such dangers, instead of tempting us to stretch our natural systems even further through technological shortcuts.

We also need greater courage by scientists in speaking out in support of basic and applied research, coupled with greater creativity in explaining to the rest of us how the results of this research are essential to a humane and healthy society. Dr. Max Tischer, professor emeritus of Wesleyan University, offered some sound advice in accepting recently the Gold Medal of the American Institute of Chemists. He said, ". . . Deep down, I believe that the scientific enterprise is not going down the drain. But nevertheless, if it is to survive and prosper as one of man's noblest accomplishments, today's and tomorrow's

generation of scientists, the young and the mature, must be enormously more dedicated, resourceful, and industrious and ever mindful of their obligations to society."

Congress, for its part, must be more willing to listen and take seriously such testimony when it is offered. This will require greater discipline and maturity, especially a willingness to eschew the demand for short-term relevance for every scientific enterprise.

We must also be willing to spend more time evaluating the merits of R&D proposals in their infancy and less time in nit-picking and second-guessing once the project is approved and underway. This new maturity on Capitol Hill will come as stronger bonds of trust and mutual respect are forged among scientists and engineers, political leaders, and the public.

I have already suggested that no person or group can be the source of all knowledge or guidance in defining an R&D strategy keyed to a more mature understanding of the benefits and limits of science and technology. All of us have an obligation to participate. A considerable portion of the agenda of the Subcommittee on Science, Technology and Space will be devoted to this issue through a continuing series of hearings and studies that will commence in September.

Congress is well suited to provide a public forum for examining the relationship between the purposes of government and the needs of society. Among the 17 specific powers of Congress enumerated by the founding fathers in Article I, Section 8 of the Constitution is one "to promote the Progress of Science and Useful Arts." Beyond this constitutional mandate is the obligation of the Subcommittee to exercise vigorously its legislative and oversight responsibilities for science and technology. This will be done. Our efforts will be guided by the 13 goals for R&D contained in the Science Policy Act enacted last year.

We welcome the participation of the Executive in this effort. In passing the Science Policy Act, Congress set in place the foundation for a cooperative and productive relationship with the federal R&D community. In particular, the Office of Science and Technology Policy, directed by the President's Science Advisor, should be the focal point for a thorough review of the government's total R&D effort.

As you know, the Executive Office of the President will be the object of President Carter's first reorganization plan. Among the options being considered is one that would fold the OSTP into a broader office of policy evaluation. Such a decision would be a major setback in any effort to bring greater order and purpose to federal R&D activities. It would be vigorously opposed on Capitol Hill.

We hope that the reorganization plan will spell out how the White House intends to carry out the Congressional mandate to conduct a major two-year survey of the condition of science and technology in the United States. There is every indication that the President's Committee on Science and Technology, mandated by the Science Policy Act to conduct this inquiry, will not be appointed. The study itself has not begun, even though an interim report is due this August. Congress expects from the Administration both an explanation of what went wrong and a suggestion of where we go from here.

Dr. Albert Einstein, in a brief foreword written for Lincoln Barnett's outstanding little book, The Universe and Dr. Einstein, expresses the spirit and integrity that guide us in these endeavors. The greatest scientific figure of this or perhaps any century wrote: "It is of great importance that the general public be given an opportunity to experience -- consciously and intelligently -- the efforts and results of scientific research. It is not sufficient that each result be taken up, elaborated, and applied by a few specialists in the field. Restricting the body of knowledge to a small group deadens the philosophical spirit of a people and leads to spiritual poverty."

It is time that we followed Dr. Einstein's admonition more faithfully.

CONGRESSIONAL ROLE IN R&D BUDGETING

Moderator: The Honorable Ray Thornton, *(U.S. House of Representatives)*

Panelists: Hunter L. Spillan, *(Committee on Appropriations, U.S. House of Representatives)*

Robert B. Clark, *(Committee on Appropriations, United States Senate)*

Sanford A. Lakoff, *(Professor of Political Science, University of California, San Diego, and Member, AAAS Committee on Science and Public Policy)*

N. Richard Werthamer, *(Chairman, New York State Energy Research and Development Authority)*

Herbert Roback, *(Director of Studies for the Commission on Federal Paperwork, and Author of Section on "Congress and R&D Budgeting" in Research and Development in the Federal Budget: FY 1978)*

Panel Session Summary

Congressional Role in R&D Budgeting

Topics addressed during the session included:

- *The effect of the media on Congressional review of R&D budgets.*
- *The interaction of the scientific and legislative communities in the appropriations process.*
- *Congressional capabilities for review of R&D budgets.*
- *The value of adversary hearings in the Congressional R&D budget process.*
- *The involvement of state governments in the support of R&D.*

Introduction

The Honorable Ray Thornton opened the panel discussion by focussing on the confusion that exists in the federal budget process. At least ten Congressional committees are directly involved in reviewing the federal R&D budget, and this "scattering out" makes it difficult to define and develop policies. The necessity for coordinating with the Executive Branch further complicates the process although the new statutory provisions for directing and coordinating research and development through OSTP and the Office of the Science Adviser hopefully will provide new direction. Also, the restraints of some governmental policies cause confusion. For example, varying provisions of patent policy often inhibit scientific research. Mr. Thornton urged the panelists and participants to examine these concerns, take a close look at the budget institutions, and consider ways to disseminate scientific information and maintain a viable connection between the legislative and scientific communities. The Congressman concluded by stating that the nation must eradicate poverty in that most precious resource, the quality of men's minds.

Prepared Presentations

Hunter L. Spillan first discussed the role of the media in science and public policy issues. As an example of the problems in media coverage, he observed that in reporting on a recent bill before the Public Works Subcommittee, although 60 percent of the monies considered were for energy projects, the press ignored energy research and focussed instead on the eighteen water projects included in the legislation. As a result, despite the fact that the committee and its staff were more concerned with the energy issues, floor debate included thirty minutes on energy and three and one-half hours on the water projects. He felt the confrontation on the eighteen projects was built by the media and noted that no one even knew of the increases in solar and fusion research included in the legislation. Mr. Spillan also observed that topics such as a national water shortage which could affect the Washington area by 1985 are ignored by the media. Because of the misfocussed concerns of the press, the public often does not concentrate on issues of truly national impact.

The confusion and complexity of the budget process again received attention as Mr. Spillan observed that last year the ERDA Administrator had to appear before thirty-five committees or subcommittees. Such a cumbersome system in which no one wants to give up responsibility will inevitably cause problems in achieving satisfactory R&D programs.

A further problem is the difficulty in explaining the benefits of research. Regardless of the difficulty, however, the scientific community must develop better arguments for the support of basic research. Since R&D is one of the few controllable budget items, misunderstanding of its value makes it particularly vulnerable to attack. This is especially true since it is so easy to cite examples of basic research that sound absurd. The fact that some individuals put too much faith in one technology, such as solar, and believe that it will solve all energy problems, causes further difficulties in ensuring an adequate base of R&D support.

The President's calls for a balanced budget combined with the difficulties of defending R&D expenditures indicate that growth in federal funding for R&D is doubtful. Mr. Spillan suggested that the message will be for the private sector to come up with research funds on its own.

Robert B. Clark felt that Congress needs the objective, expert advice of the scientific community. With all the wealth of material available to the Congress and with all the resources at hand, it is essential that these be complemented by those most interested parties outside of the government who can bring their training and, hopefully, their objectivitiy to help the Congress make the decisions and choices between priorities, which is what the budget process is.

Mr. Clark then set the context within which the Committees on Appropriations must work in making their decisions as to funding of R&D programs. When decision time finally comes, the Committees on Appropriations are close to being a court of last resort, and a court with very real limitations on what they can do to change the decisions that have gone before. By this time, the various government agencies have gone through their annual excrutiating confrontation with OMB, and the agency budgets, in almost every case very much squeezed down from the original proposals, have passed through the funnel of the White House and reached the Congress. Then come the Congressional budget committees' actions into which the Appropriations Committees and the legislative committees have input. Often Congressional budget limitations do not decrease the budget submissions and, in fact, in many cases they have increased it. The next processes are those of the authorization committees in which, in most cases, the actual limits are set on appropriations. Again, there are often increases, not cuts, in the budget request.

Now, at the end of the line come the Appropriations Committees. It is obvious that short of a dramatic national emergency, or at least national urgency, deep changes will not then be made in the R&D budgeting in the bills the Appropriations Committees, and then the Senate and House, will consider.

At this final stage, if anyone feels there is a dislocation in R&D funding, it is really not so hopeless as it might appear to effect some changes. Ideally, the recommendations for major changes in the budget should best have been expressed before this stage. But, it is not too late since there is usually room to rearrange the money figures within the budget limitations set by the Administration, the authorizing committees, and the Congressional Budget Office. As to the latter, it has been demonstrated, after all, that a third concurrent resolution can be passed increasing budget limitations.

As a note of caution, Mr. Clark explained that the thirteen subcommittees that make up the Committees on Appropriations in the Senate and in the House look at the budget presentations by institutional line-items. There is no one R&D budget. Even within the agencies, R&D may be divided and included within several different line items. Thus, if one's

interests go beyond specific, usually applied research, or development of a certain project, one needs to do some homework to make a presentation coherent, even comprehensible, to those who work on appropriations. With certain exceptions in the NSF and NASA budgets, one's interest in certain scientific disciplines or functions, rather than specific projects or programs, will have to be tailored to the realities of how budget requests are considered by the various subcommittees. If people feel there is not sufficient applied research in a given field, or if people feel support for basic research should be broadened, then of course they can appear before the Appropriations Committees as witnesses and document these opinions. They can visit committee and Congressional staff and write letters or contact Congressmen and Senators. There is nothing wrong with good, strong, objective lobbying. This is one important way the Congress is led to focus on what people are thinking.

An example of what can be attempted is a recent move in the Appropriations Committee to add an unbudgeted $3.5 million and 200 researchers to the EPA's laboratories and research facilities. This increase was made because Committee staff and a very few lower echelon EPA researchers separately, and unaware of each other's endeavors, took a hard look at EPA's efforts in relation to the country's needs for establishing better criteria for regulations affecting the environment. It seemed to them that there was not sufficient basic research or applied research being conducted to provide the government, the agency, or the Congress with sufficient and reliable facts on which to base determinations about off-shore oil development, water pollution, and other major issues. No trade-off in funds was offered; simply, a certain Senator and others led a fight for something they believe in.

Within the constraints cited, if the scientific community can concentrate on chosen target areas, if it can choose its priorities, if it can decide the emphasis it wishes to place between the divergence of scientific disciplines it represents, it can very definitely influence the federal budget process even when the over 100 steps have been taken from budget formation down to the courts of last resort, the House and Senate Appropriations Committees. Certainly, the scientific community should look for ways to add support to those R&D programs or projects that it is convinced are good and solid and that seem to be in trouble in the Congress. It should attempt to determine its own, collective priorities, and then interact with the whole budget process. It is unfortunate, Mr. Clark observed, that so much of R&D and particularly basic research has no real political constituencies. The community's efforts, typified by this meeting, to prepare itself for participation in the government R&D budget process, can help fill this void.

Sanford A. Lakoff opened his remarks by giving an "academic amen" to what the other panelists had said. He reiterated an earlier speaker's comment that James Madison would certainly be pleased to see that the federal government and its budget system were indeed pluralistic. The important question is whether such a divided and scattered system is a virtue or a vice. As a virtue, the system does allow the representation of diverse interests and the input of various points of view. It allows us to avoid arbitrary policy and ensures oversight of the Executive Branch. As a vice, the budget system can lead to a situation, as in the case of the Clinch River project, where one interest group can concentrate and overpower other interests. It is also possible that conflict between the authorization and appropriations committees can result in what James MacGregor Burns called "the deadlock of democracy". Scientists are ambivalent in their view of the pluralistic system. In times of an expanding budget, they like the various points of access that a pluralistic system gives. When the budget is tighter, they often feel that this same pluralism is a hindrance in tracking down sources of support for R&D and would like a more unified system such as the British and French have.

Professor Lakoff expressed doubt that a new "more rational" budget system would be found, for there have been many "magic wands" that have not significantly changed the character of the budget process. He regretted the morning speakers' emphasis on cost/benefit analysis, reminding the audience that it is difficult and sometimes impossible to quantify the benefits of R&D. Repeating the point that R&D is one of the few controllable items in the budget, he warned that it is particularly sensitive to the political climate and told the scientific community not to be surprised if Congress did not take its cues from the scientific community, but instead took them from its perception of what the people wanted. The scientific community must convince the Legislative and Executive Branches that R&D is the bedrock upon which other progress depends and must explain that if they neglect the health of the various research institutions and fail to ensure a supply of trained personnel, it will be impossible to re-order R&D with each major shift in public priorities.

Warning the scientific community that it cannot afford to remain aloof from the political process, he suggested ways for the community to play a role in federal budgeting. The first is through the regular channels of NSF, OSTP, NASA, and ERDA and their relationship with Congress and the Executive. Second, professional societies can provide testimony and information. Third, the Congressional Science Fellows serve an important function. Despite one Fellow's statement that entering the Legislative Branch was like going into a bizarre feudal system, thirteen out of thirty-six Congressional Fellows

have remained with the Congress. One, for instance, alerted Senator Kennedy to the necessity for support of basic research in industry now that scientists, unable to find jobs in the academic world, have moved into industry. More generally, the Fellows can provide a source of much-needed, continuous scientific knowledge and analysis to Congress. The Congress must help inform itself while the scientific community must always remember it lives in a political universe.

The discussion of the proposal to create a Department of Energy is an example of successful contact between the legislative and scientific communities. At first, there was to be no focal point for R&D in the Department. However, an institution concerned with support of scientific research pushed hard to have such a provision included. Thus, while there are opportunities for R&D interests to influence legislation, there will be difficulties since the R&D constituency, with its small colleges and businesses and its large universities and industries, is not at all unified. Professor Lakoff encouraged efforts to form a more unified group, and would welcome AAAS' assistance in allowing such a group to provide scientific input into the budget process.

N. Richard Werthamer focussed on three major issues. The first concerned the Congressional review of the R&D budgets. Dr. Werthamer felt that Congress is doing a better job than it ever has before. The Congress has expanded its staff capability for dealing with budget review, but there is still room for improvement. The discontinuity between the authorization and appropriations processes is one problem. He suggested that the staffs of the committees involved in each process might do joint work, and the committees themselves might hold joint oversight hearings. These proposals would give the committees a common basis of fact and save the various agencies the task of preparing the same testimony twice. In discussing what resources were available to Congress in reviewing the R&D budget, he described the OTA review of the ERDA budget that was carried out two years ago. In about two weeks, utilizing outside experts, OTA was able to identify key issues, ask good questions, and prepare its findings in a usable format. The exercise allowed Congressional staff to participate on an hour by hour basis, thereby helping to familiarize them with the issues under consideration. Furthermore, OTA had the benefit of having funds to pay experts for more than one hour's testimony. This exercise could provide a model for future projects.

The assistance provided by the professional scientific societies to Congress as it reviews the basic research budgets was the second issue. Dr. Werthamer felt that the societies are doing a poor job in this area. They do not seem to understand the political problems under consideration, and

they tend to have parochial interests. Further, they are not well organized for dealing with the budget process. While some senior scientists skilled in administration can manage to have budget cuts in their large projects restored, this often causes resentment among the average scientist who is left with cuts in his smaller project. The scientific societies might organize for effective action in addressing the vital question of the value to society of science research, and the AAAS is a potential coordinator for such an effort. Without that basic understanding, legislative problems with R&D will continue to exist.

The third issue related to the way in which the federal government was supporting state government in R&D efforts. Dr. Werthamer first observed that more and more R&D is being used in the civilian sector for social purposes rather than being used to buy hardware for a government controlled enterprise. In such a context, the federal government needs intermediaries between itself and the people to ensure that an available technology is used. Solar hot water heating is an illustration of such a civilian technology. Everyone wants it to happen, and there is a system that works; however, this is not enough. To achieve the goal of ten million units on top of homes, consumers must have confidence in the product, product standards must be set, labor must be trained, and the local utilities must be involved. The federal government cannot accomplish all this by itself; it must have the states as partners and decentralize R&D. This is true for all projects which demonstrate technology on a large scale. The New York State Energy Research and Development Authority is an example of how this may be accomplished with a small budget relative to what the federal government spends in similar projects.

To form a chain between the federal government and the people, the states must be involved in planning from the beginning. Merely handing them funds with orders to complete a project will not work.

Herbert Roback observed that the days of the old whip-cracking chairmen were gone; now there are new, younger people and different concerns in Congress. He, too, noted that the federal government is pluralistic, and felt that R&D is probably better off for it. Although reforms and proposals to centralize are easy to put on paper, the changes will not occur in practice. The scientific community, too, is diverse, and, at any rate, Congressional priorities are not necessarily those of a scientific constituency even if a unified constituency did exist. Political concerns always come first.

Congress wants objective information even if it can not or does not always use it. To make its needs known to Congress, the scientific community can organize a seminar or

provide testimony, but to be really effective in influencing legislation, it must lobby. And, the new lobbying amendment will probably require that all groups attempting to influence legislation must register as lobbies. However, if a scientific organization does register, it can lose its stature as an objective organization.

In conclusion, Mr. Roback did offer the hope that although Congress is unpredictable and complex, it has a good many intelligent, hard-working, underrated members. They, in fact, often have knowledge and information that politics dictate not be revealed in public.

Discussion

Discussion following the panel presentations focussed on three issues: the general role and capabilities of the Congress in the federal R&D budget process; various ways to ensure state involvement in support of R&D; and the value of adversary hearings in the legislative R&D budget process.

The discussion of the Congressional role opened with a word of appreciation for Hunter Spillan's and the Appropriations Committee's roles in adding $15 million to the gas cooled reactors in the ERDA budget. Mr. Spillan noted that it was somewhat unfortunate that no one ever wished to see his or her budget cut despite the probability that there were programs still in existence that had outlived their usefulness. Later in the discussion, both Mr. Spillan and Mr. Clark emphasized that the split between the authorization and appropriations processes made it imperative that the committee staffs communicate. Otherwise, the Appropriations Committees might appropriate funds beyond authorizations. Both panelists did say that such communication did occur.

In a question from the floor, William Carey noted that all of the discussion had appeared to indicate that Congressional budgeting was scattered, yet it seemed to him that the Legislative Branch was in a better position for policy analysis and research involving science and technology than was the Executive Branch. He mentioned GAO, OTA, and the Science Division of CRS as examples of the type of support Congress has available. To his mind, there is a rich output of quality research and analysis, and he queried how well the output was utilized. He also asked whether the Congress was able to deal with certain problems that required lead-in time for their solution. Mr. Spillan noted that the Members with whom he was familiar used these resources and demonstrated familiarity with the information they provide. He also felt the way in which the Members managed to cope with large quantities of information and analysis was impressive. Congressman Thornton

observed that members do try to inform themselves, but in the final analysis, are dependent upon the competence of their staffs. The staffs have the education and experience to understand the technical and scientific detail of certain policy matters, and he suggested that the scientific community establish a rapport with them. In this way, the community can ensure that the Congress will understand R&D issues.

Turning to another level of government, a question stimulated discussion regarding the methods by which R&D funds could be received from state governments. Dr. Werthamer felt that the best strategy was for state R&D agencies to see that the state received its share of federal funds. In addition, such agencies could work with potential performers to see that they were organized to take advantage of any funds offered. Professor Lakoff then raised the issue of the relationship between state legislatures and state-supported higher education. He mentioned Pennsylvania and Massachusetts as states in which the members of the state legislatures have access to people in the state universities. In California, members of the University of California faculty do research and identify concerns for the state legislature. He felt this was of particular value in overcoming misunderstanding between the public and higher education, and he was optimistic about the success of such programs. Dr. Werthamer then suggested that faculty sabbaticals could be used to assist the legislature on matters related to science and technology.

A question regarding the New England regional veterinary school led to a brief discussion of ways to get funding for similar projects. Mr. Clark made the practical suggestion that some measure of local, state, or regional funding, significant enough to indicate the value of a project, was the best way to receive consideration from the Appropriations Committees. Since state budgets are even more pinched than the federal budget, a good mix might be as much as 75 percent federal support and 25 percent local, state, or regional support. He emphasized that support that evolved from the grass roots is the most effective.

A discussion of adversary hearings (which allow experts on two sides of an issue to confront each other) was introduced by a participant who felt that such hearings had discredited the scientific community. Mr. Roback first responded that since Congress liked differences of opinion, it was up to the scientific community to decide whether it wanted to get involved. Although he admitted that there were certain problems with the process, he did not feel that the hearings diminished the community's stature since everyone understands that scientists disagree. The hearings, in his opinion (which was shared by most members of the panel), provide more "grist for the mill." Mr. Spillan added that this type of hearing

enabled everyone to be fully informed on the Clinch River breeder reactor and helped everyone to understand both sides of the issue. The adversary hearings, in short, were a good way for Congress to review the project. Dr. Werthamer thought that this was an effective means for scientists to play a role in the budget process, and also suggested the alternative model of a study on nuclear energy carried out by the American Physical Society that utilized the abilities of individuals who had not been involved in the controversy.

Professor Lakoff made the general observation that there is no alternative as effective for the scientific community as the willingness to go public. Otherwise, the public will feel that the scientific community is attempting to inflict its will upon the nation. The public must learn that scientists are not "from Olympus." Even if there are some problems, open discussion and possible disagreement on policy issues are vital in a democracy. Furthermore, if the public should feel that scientists are withholding their real opinions, there will be a backlash of public opinion.

On the topic of the hearings process, Professor Lakoff noted that the usual system of serial testimony often leads to ambiguity, yet he cautioned that it is difficult to hold a truly effective adversary hearing without courtroom rules and a judge to rule on evidence. He felt that a structure could be developed that would allow better confrontation between opposing views with better control over the interchange. This could help clarify the ambiguities of serial testimony. Mr. Clark stated that his committee had had little experience with adversary hearings, but that the practical difficulties of balancing views and predictable opinions in a typical hearing often meant that the amount of information gleaned was minimal.

Congressman Thornton warned of problems with an adversary hearing. While he admitted that an adversary hearing could result in a wide ranging inquiry and had great advantages when it came to supplying information, he noted that an adversary situation always implies that one side is right, and the other wrong. Actually, there is more often a measure of each on both sides. He also reminded the audience that scientific truths are found in the laboratory, not in a courtroom. Hence, one must be extremely careful not to let the adversary process determine a scientific article of faith.

HOW SHOULD R&D DECISIONS BE MADE?

Moderator: Ruth M. Davis, *(Deputy Undersecretary of Defense Designate for Research and Advanced Technology, and Member, AAAS Board of Directors)*

Panelists: Philip B. Yeager, *(Committee on Science and Technology, U.S. House of Representatives)*

Jeffrey R. Cooper,* *(Energy Policy and Planning, Executive Office of the President)*

Willis H. Shapley, *(Consultant to the AAAS for the R&D Budget Analysis)*

Eliot R. Cutler, *(Associate Director for Natural Resources, Energy, and Science, Office of Management and Budget)*

John C. Calhoun, Jr., *(Vice-President for Academic Affairs, Texas A&M University)*

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* Mr. Cooper replaced Alvin L. Alm.

Panel Session Summary

How Should R&D Decisions Be Made?

Topics addressed during the session included:

- *The tools and analytical processes used in making decisions on R&D.*
- *A "strawman" system for R&D budget decisions--Controlled Commitment Budgeting.*
- *The support for basic research in the context of national needs.*
- *Decision-making in energy R&D.*
- *The relationship between the federal R&D system and the national R&D system.*

Introduction

Ruth M. Davis opened the session by pointing out the difficulty in arriving at an answer to the question posed to the panel--How should R&D decisions be made? In considering the question, however, the panel and participants must keep in mind the realities of R&D budget decisions--the 123 steps in the budget process, the 3 overlapping budget cycles proceeding at one time, and the more than 90 agencies and departments involved. The topic must be addressed in practical terms and not be consumed with references to decision trees, decision matrices, or decision systems analyses.

To set the stage for the discussion, Dr. Davis provided some statistics* on the differences in the monetary magnitude and the scope of decisions on R&D budgets. She differentiated between single decisions and multiple decisions on the same topic, between decisions to turn down projects and to turn on projects, and between small, micro-monetary decisions with wide impacts and large monetary decisions also having wide impact.

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* The numbers are taken from the AAAS report, Research and Development in the Federal Budget: FY 1978.

An example of a single decision is the proposal by the Carter Administration to reduce the funding of the Clinch River breeder reactor by $84.4 million. This amount is greater than the entire R&D budget for HUD proposed for FY 1978, which is $60 million. Clearly the decision on the Clinch River breeder was made in an entirely different way than were the multiplicity of decisions culminating in a single number of $60 million for the R&D budget of an agency, although both processes were intended to result in the best for the national interest.

A second example came to mind from the recent decision of the U.S. to block a computer sale to Russia. A year ago an R&D budget decision was made not to fund research on safeguards for preventing the diversion of computers from their intended end use. This was a miniscule decision in dollar terms--less than $1 million--but, the repercussions have been two articles by Jack Anderson and a letter to the President signed by 216 congressmen expressing their strong opposition to the sale of a single computer system to Russia and citing the lack of practical methods in the U.S. for monitoring the uses to which a computer is put. For want of a good R&D decision, an opportunity for preventing a confrontation between economic and national security interests has been lost.

Still a third example is the single decision made by Congress in FY 1977 to reject the R&D portion of the Navy's program to rebuild the fleet. This was a $200 million decision with complex, far reaching impacts on industry, on the Navy, and on future U.S. statements of our military strength. This single point decision contrasts sharply with the multiple decisions in over 12 agencies that resulted in a net projected increase of $205 million in R&D funds to colleges and universities from FY 1977 to FY 1978. The universe affected, however, is at a maximum 2500 colleges and universities as opposed to the numerous and various institutions affected by the decision on the Navy's fleet.

In concluding, Dr. Davis paraphrased a statement on decision-making made by Admiral Radford after World War II. A decision should always be avoided in favor of an answer. If the staff work is good, the information provided contains the answer. If good information is not provided, then one has to make a decision.

Prepared Presentations

Philip B. Yeager, although uncertain that an R&D budget exists, began his remarks by trying to prove that one does. His argument was based on reference to three parts of the Science Policy Act of 1976.

Title I of the Act states that federal funding for science and technology represents an investment in the future which is indispensable to sustain national progress and human betterment and that there should be a continuing investment in science, engineering and technology that is commensurate with national needs and the prevalent economic situation. The Act goes on to say that the federal government should maintain central policy and planning elements in the Executive Branch that assist federal agencies in a) identifying public problems and objectives; b) mobilizing scientific and technological resources for essential national programs; and c) securing appropriate funding for programs so identified. Finally, the Act states that the duties of the new science adviser are to a) advise the President on scientific and technological considerations with regard to the federal budget; b) assist OMB with an annual review and analysis of funding proposed for R&D in all federal agencies; and c) aid OMB and the agencies throughout the budget development process.

These statutory requirements for the Executive Branch do constitute policies related to budgets for R&D. It should be emphasized, furthermore, that the pending reorganization of the White House cannot affect these requirements.* The President can change the organization only. If he does, he still must provide a means for the functions required by the Science Policy Act to be performed in some other way. Thus, any reorganization of the science policy apparatus in the White House may have an effect on how R&D decisions are made, particularly in the Executive Branch.

The question posed to the panel--How should R&D decisions be made?--implies that something different or better is possible. But, is it? Any procedure based on the principles of a democratic system will be inefficient. Many points of view must be considered on any issue. In thinking about improving R&D decisions, however, Mr. Yeager presented four ideas for consideration.

First, Congress might consider an R&D budget as a whole, as one unit. To do this would require the creation of a Department of Science and Technology or the equivalent, the thought of which makes scientists, technologists, and federal agency personnel shudder. Last year the House Committee on Science and Technology developed a justification for such a department, and at one point its creation was included in the Science Policy Act, although primarily for discussion purposes only. Of course, the provision did not survive. An

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* The reorganization plan for the White House was sent to Congress on 15 July 1977.

interesting feature of the discussion was the often expressed view that the Bill should not include anything that looks like science is being supported for its own sake. By implication, then, science has no place except to develop technology. Mr. Yeager, on the other hand, does not understand why the federal government cannot support science as an end in itself; why scientific knowledge is not worth producing for its own sake. Why isn't the rationale applied to the National Endowments for the Arts and Humanities applicable to science?

The second point pertains to the possibility of a two-year cycle for the federal budget as has been proposed by the Senate for the authorization of NSF. This budgetary modification is worth serious consideration and probably will be examined closely during the next two or three Congresses. On the positive side, such a procedure would provide more sustained funding, and the House and Senate would need to spend less time on annual authorizations. On the negative side, although in theory there would be more time for oversight, Congress would probably devote less time to examining the practices of the agencies. R&D deserves to be looked at every year due to the often rapid changes in the needs for R&D.

Third, the budget decision process might be improved through better liaison between the authorization and appropriation processes. Presently, liaison is carried out by individual staff members who are especially gifted in this way, and not many are. Current action on the NSF RANN program is illustrative of the differences that arise. The authorization committee is proposing budgets in the high $70 million range, while the Appropriations Committee has cut the current $67.6 million budget by 35 percent. At the same time, the authorization committee has written into the Bill minimum spending requirements for certain projects which together with the proposed reduced appropriations would mean that 75-80 percent of the RANN budget would be dictated by Congress. Better cooperation between the committees might alleviate some of these difficulties. In the years ahead, the possibility of merging the authorization and appropriations procedures is likely to receive increasing attention.

Finally, some means for getting a better handle on the results that flow from the use of federal funds to support R&D would serve to improve the process of making R&D decisions. The federal government usually proceeds on a "faith or fear" basis--it is usually an article of faith that a certain amount of funds will go to research and that something useful will come of it. Our experience suggests that we do benefit, but it is difficult to delineate specific correlations between money spent and benefits received in terms of new knowledge and uses of it. This is an area in which the new Office of Science and Technology Policy might become involved.

Jeffrey R. Cooper* directed his remarks to the role of decision-making and funding in energy R&D. Energy R&D is different than most other areas of federal R&D in that the results must compete in the commercial marketplace. This provides a strong rationale for the need for economic tests in deciding on both levels of funding and projects to be supported. The emphasis on this need changes, however, depending on the type of research. Mr. Cooper classified energy R&D into four categories: (1) short-term, focussed primarily on commercialization; (2) medium-term, focussed primarily on demonstration both of commercial utility and technical feasibility; (3) long-term, directed at proof of scientific and technical feasibility; and (4) basic research.

R&D is conceived of as a means for producing information, in the broadest sense, rather than products. Therefore, in the R&D enterprise, failure ought not be a bad word. Even failure should produce valuable information, particularly in long- and medium-term research where multiple paths, options, and technologies are available for reaching the same end. In using R&D to reduce uncertainty as a technology proceeds from scientific test to the commercial marketplace, failure plays an important role in deciding which options are not viable, and therefore, do not warrant the allocation of additional resources. Hopefully, the R&D process also produces some successes and shows the optimal paths to pursue toward commercialization.

The National Energy Plan is designed to establish a coherent framework for making decisions on the magnitude and internal priorities for energy R&D. The question of priorities refers first to the mix between short- and long-term projects and funding, and second to the mix between the various options for achieving a particular goal. In short-term R&D, the emphasis must be on commercialization, correcting market imperfections caused by institutional barriers and lack of a rational crisis mechanism. The entire R&D process with the exception of basic research ought to be directed at moving technologies from studies of scientific feasibility (long-term) to commercial demonstration of feasibility and costs (medium-term) to commercialization (short-term), which requires overcoming legal requirements and other institutional barriers and testing economic viability. The National Energy Plan assures ample support for short-term R&D in providing that the technological queue will be available from which products can be drawn.

Consideration of medium-term R&D revolves around the role

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* Mr. Cooper, Energy Policy and Planning, Executive Office of the President, replaced Alvin L. Alm.

of demonstration projects--demonstration of technical feasibility and demonstration of commercial worth. In the development of energy technologies, it would be preferable to maintain many options in the early stages while much information is being produced at low cost. The options would be narrowed on the basis of scientific and technical studies, and only those with the most promise for viability in the marketplace would be moved to the final stage of demonstration, which is half-scale or full-scale commercial demonstration. This last step, commercial demonstration, is the most costly. Supporting large numbers of multiple commercial demonstrations would result in an intolerable burden on the federal budget. At the same time, commercial demonstrations are needed to transfer technologies from the laboratory into the marketplace in areas where commercial lenders are willing and able to make the requisite financing available to commercial users. In the energy area, this participation by the commercial sector is critical, because it is this sector that will be operating the technologies that reach commercial fruition.

In long-term R&D, the role of the federal government is central. The federal responsibility in this area is a natural consequence of the differential between private and social rates of return for projects requiring massive funding and long gestation periods and for which the future market conditions are uncertain. In many cases, and certainly for FY 1978, long-term R&D is the most sizeable portion of the budget for energy R&D. The purpose of long-term R&D is to reduce the uncertainty regarding scientific and technical feasibility, and thereby, to provide the basis for deciding which options should be moved toward commercialization. One of the basic guidelines for the support of long-term R&D, however, is to foster projects because, if successful, they will meet a societal need at a competitive cost and not solely because they are technically feasible. Mr. Cooper cited the Clinch River breeder reactor as an example of a project that is technically feasible, but due to its economic, social, and environmental impacts does not meet national needs. Hence, the Administration has recommended that it be substantially decreased as a long-term R&D project. In concluding the discussion of long-term R&D, Mr. Cooper emphasized that due to the scarcity of federal R&D funds, the government should not subsidize existing commercially viable technologies, but rather focus resources in areas in which the technologies are not yet available.

Basic research was the final category discussed. Determining support for basic research through cost-benefit analyses is not possible. In fact, attempts to measure the significance of basic research through tests of utility or relevance run the risks of both bad analysis and significant underinvestment. On the other hand, support of basic research is a national overhead, and should not be viewed as a blank check.

Mr. Cooper felt that tools are simply not available for setting priorities for the allocation of the limited federal resources available to support basic research. A tool that may help is the "strawman" system (Controlled Commitment Budgeting) discussed later by Willis Shapley and described in Chapter 5 of the AAAS report. Many features of this system were utilized in preparing the budget for fusion R&D in ERDA. As research continues in new energy fields, such as fusion, solar, and geothermal, hopefully the areas of uncertainty will decrease, and consequently, decisions will become better. But, much of decision-making will continue to be tentative, intuitive, and qualitative--and that might not be all bad.

Eliot R. Cutler discussed three basic problem areas that he has encountered in the spring review phase of the preparation of the FY 1979 budget: 1) supporting basic research in the context of national needs; 2) avoiding the support of R&D simply to expand our technological capabilities (different than expanding the knowledge base); and 3) avoiding the takeover through federal programs of the responsibilities of the private sector.

With respect to basic research, the federal government does have an important role in assuring an adequate national effort in increasing the knowledge base. Although the Administration has not yet developed a policy in this area, it is clear from the President's statements and the time he has spent in discussing the programs of the R&D agencies that he is very interested in the subject.

In addition to the adequacy of the knowledge base, other issues related to basic research that need more attention are the relationship of basic research to critical national problems and the need to encourage further investment by industry in basic research. (This latter issue is discussed at the end of the presentation.) In order to stimulate more basic research applicable to national problems, we need to identify the problems and needs better. This is a role that OMB can perform as it assesses the basic needs and basic problems that can be the subject of substantial government funded basic research. A current example of a problem that might be illuminated by more basic research is illustrated by the limitations on photochemical oxidants imposed by the Clean Air Act. The levels of photochemical oxidants that cause a health problem are known. The oxidants, however, are not emitted from any smokestack, but are formed from photochemical reactions between hydrocarbons and nitrogen oxides. Therefore, the levels of emissions of these compounds must be regulated. But, we do not know the rates nor the various conditions under which these substances react to form the oxidants. We may not know enough to intelligently establish effective regulations,

and perhaps more funding should be provided for basic research in this area. If so, should such research be supported by EPA or by NSF? Without answering the question for this specific case, NSF does have a role for encouraging basic research in national problem areas, while also funding basic research to increase the knowledge base. These two functions are not incompatible.

In considering the support of R&D merely to expand our technological capabilities, we must recognize that there may be limits to the amount of technological capability that we can afford. The space program in the NASA budget serves as an illustration. Some people would like the U.S. to show the world that we can operate in space in larger and more dramatic ways. In their minds, the next logical step in man's program in space would be the creation of a permanent space station or a solar power satellite. Before embarking on such efforts, however, we must ask whether we can utilize and expand our present capabilities. Continual creation of new capabilities--technology push--not only can be extremely costly, but also may lead to expensive white elephants. Because technological capabilities can begin to drive one's perception of needs, we must identify needs first. That is, before committing to a permanent space station, we need to know what the station would be used for and why we need it.

The federal government must be careful in not overtaking and replacing the private sector in funding R&D. This is not to say that the private sector is doing as much as it should or could, but rather to say that given a gap in R&D funding generally, there is a legitimate question as to whether the federal government itself ought to fill that gap. The federal government has a role in supporting high risk, long-range R&D. But, it should avoid excessive funding of "technological winners" where there are incentives for the private sector to act. For example, in the area of solar heating and cooling demonstrations, the federal government will have funded 10,000 separate solar heating and cooling units. Thus, it seems time to redirect the federal effort toward long-term research in solar electric technologies and allow a competitive industry to grow in the solar heating and cooling area if there is a basis for it.

We must find ways for involving the private sector more in the funding of basic research. The federal government probably will not be able to fund a growing share of basic research, either in relative or absolute terms. Given the special nature and importance of this area, greater industry involvement should be encouraged to provide for growth.

John C. Calhoun observed that the R&D budget appears to consist of three processes: one at the agency program level; one at the Executive policy level; and one at the Congressional appropriation level. Each appears to have its own ground rules. Although the processes overlap and are intertwined, they appear to be based on separate analyses and different assumptions.

This three level system appears to be as appropriate for decisions on r search as it is for decisions on other budget allocations. What needs to be examined and perhaps changed are the assumptions and analytical processes on which the decisions appear to be based. Dr. Calhoun raised three general issues that deserve further consideration.

First, federal research budget decisions appear to be made with insufficient knowledge about the national research system of which federally budgeted research is a part. More needs to be known about the ways in which federal activity interacts with the total system. For example, the federal government acts as a funding source, as a major participant, (a performer of research), and as a stimulant or depressant to the total system. To draw an analogy, it is as though budget decisions were made on defense expenditures without an intelligence network capable of assessing the total international community and the defense capabilities existing in other countries. Our federal research expenditures analysis does not have the benefit of an equivalent research intelligence network. With greater consideration for the existence of a national research system, the budget decision maker might ask how the total system might be used to achieve the desired goal. Alternatives might be to buy into the existing capabilities rather than to create new capabilities, or to embark upon cooperative programs with other participants.

Second, there is a mismatch between the decision time cycle necessary for the federal budget cycle and the decision time cycle that applies to maintaining an effective research system. The national research effort has many of the same characteristics as a resource activity. To cite some of these:

1. Much advance exploration is necessary.

2. Although the result of the total effort is positive, the results of individual parts of the effort may be unfruitful.

3. Productivity depends upon how far advanced the development of a particular part of the resource may be.

4. As with all resources there may be many different uses.

5. The decisions that are made in any annual budget cycle are a part of the continuum of analysis and assessment of the resource. This continuum extends over many years.

The federal budget decisions on research do not appear to be made in the context of such a continuum of forward planning and assessment. The appropriate participants in the national research community should be given an opportunity to interact with federal agency research policy planners and to contribute their ideas and suggestions for research programs and policies long before the agency gets into the rigors of the annual budget decisions. We should try to obtain the assessment of the research communities on what is worth doing. As a small example, this is being tried in the sea grant program.

Finally, should the federal R&D program be the sum of the individual agency programs? Should there not be a look at the program from the total research community of the nation? Can the individual decision maker effectively analyze elements of the decision with respect to timeliness, organizational capabilities, scientific manpower, and adequacy of facilities in the absence of such a total look? It is imperative that the decision process have available the sorts of things intended in the establishment of the science advisory apparatus in the Executive Office of the President. It is also imperative that for each major area of research activity, such as for energy or defense, there be a total research community look at the program. For example, how can energy research decisions be made in the absence of an infrastructure which delineates energy as a field of knowledge?

Dr. Calhoun has less quarrel with the apparent process of how R&D decisions are made than with the tools and analyses that appear to be available to the decision maker or with the gaps in the process which if filled would make the decisions more highly related to the effective use of research as a matter of achieving national policy goals.

Willis H. Shapley summarized and amplified the ideas presented in Chapter 5, "How Should R&D Budget Decisions Be Made?" of Research and Development in the Federal Budget: FY 1978. Of the nearly 20 conditions listed in the report that a decision system for R&D budgets should meet, Mr. Shapley highlighted five:

1) The system has to provide for periodic, but not necessarily annual, "zero-base" or "sunset" type reviews. Although it is valuable to examine total

programs, it may be expecting too much to do this every year for all federal R&D projects in the $28 billion total.

2) The system should recognize the legitimacy of the federal support of R&D in three contexts: where the goal is to meet defined needs; where the goal is to increase knowledge as an end in itself; and most important, where the goal is to develop technologies, techniques, or concepts, or to demonstrate useful applications of them.

3) The system must avoid the misuse of plausible decision criteria, such as relevance tests, cost-benefit analyses, or marketplace tests of value, in cases where they are not applicable or their underlying assumptions are not valid.

4) The system must accept and find ways to work around the "lead-time dilemma" (the necessity for making decisions on future phases of R&D programs prior to the completion of current phases). Plans must be developed to anticipate success, failure, and indeterminate results.

5) The system must avoid making a one-to-one correspondence between R&D and some particular need or benefit. In most cases there are a multiplicity of results and implications both from doing and not doing R&D.

Mr. Shapley then proposed a system for making R&D decisions that is compatible with the conditions. He referred to the system as "Controlled Commitment Budgeting."* The system is not meant to be a panacea for solving problems on R&D; the judgments and difficult trade-offs will still have to be made. Rather, the intentions are to include the essential issues that need to be considered in budget decisions and to focus attention on real questions that can be answered and minimize the amount of unproductive paperwork. The system is a concept that must be tailored to each particular situation; it is not a standard procedure, a set of steps, that is to be installed throughout the government. Finally, the system is not specially for R&D decisions, but is compatible with other areas as well.

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* See the AAAS report, Chapter 5, for a more thorough description of this system. The system includes many features that are now being used to some degree in federal R&D agencies and by OMB.

The two principal features of the system are referred to as "Baseline Planning Envelopes" (BPE) and "Commitment-Evaluation Cycles" (CEC). A BPE is illustrated in Figure 1. The envelope starts with the latest approved budgets and, for the succeeding years, shows the amounts estimated to be required for approved program commitments, for expected program extensions, for allowances or changes due to uncertainties in costs of projects, and other changes that might occur over a period of years, and for an undefined planning "wedge"--an estimate of what might be applied to new programs to be started in future years. The total envelope built up in this way is then divided into elements of two types as shown in Figure 2: major programs or projects that significantly affect the total, and "levels of effort" to be applied in other parts of the program. The major program and project subdivisions are finite, substantive program options and decisions that are properly of specific concern from a financial standpoint of program need and technical content. The "level of effort" areas refer to aggregations of smaller decisions that are simply too numerous to make individually. The elements into which the envelope is divided should be tailored to the nature of the program and the needs of management in each case.

The second feature of the system is the "Commitment-Evaluation Cycle" (CEC), which is illustrated in Figure 3. Whereas BPE's are intended to be used by managers in discussing programs with the boss, the CEC would be used by managers in planning projects with the people who will do the work. First, the CEC statement would specify the work that management intends to be accomplished, in terms of results to be achieved, phases of the project to be completed, or amount of effort to be applied--whatever is the most appropriate basis for evaluation in the particular case. The CEC statement would also include a schedule, indicating the lead time necessary to get the budget approved by Congress, the period of work covered by the commitment, the period during which the work or its results will be reviewed and evaluated, and the time at which the decision will be made on continuing, terminating, or redirecting the program. Decisions to continue or redirect would require a new CEC statement, and another round in the cycle would begin. Finally, the resources allocated to the project must be specified. The hope is that preparation of CEC statements will result in a clearer understanding by all parties involved of what is expected, when it is expected, and how it will be evaluated.

Discussion

The decisions on R&D budgets made by the federal government have a significant impact on other sectors of the national R&D

Figure 1

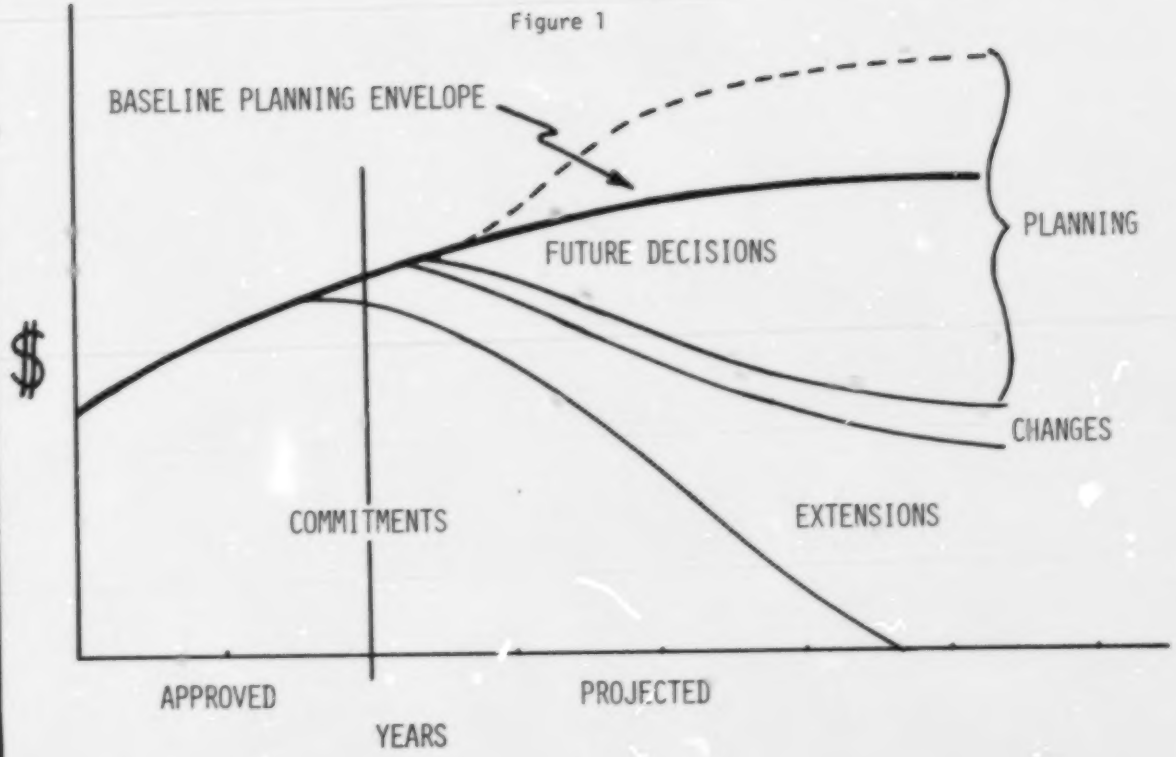

BASELINE PLANNING ENVELOPE
PLANNING
FUTURE DECISIONS
$
CHANGES
COMMITMENTS
EXTENSIONS
APPROVED
PROJECTED
YEARS

Figure 2

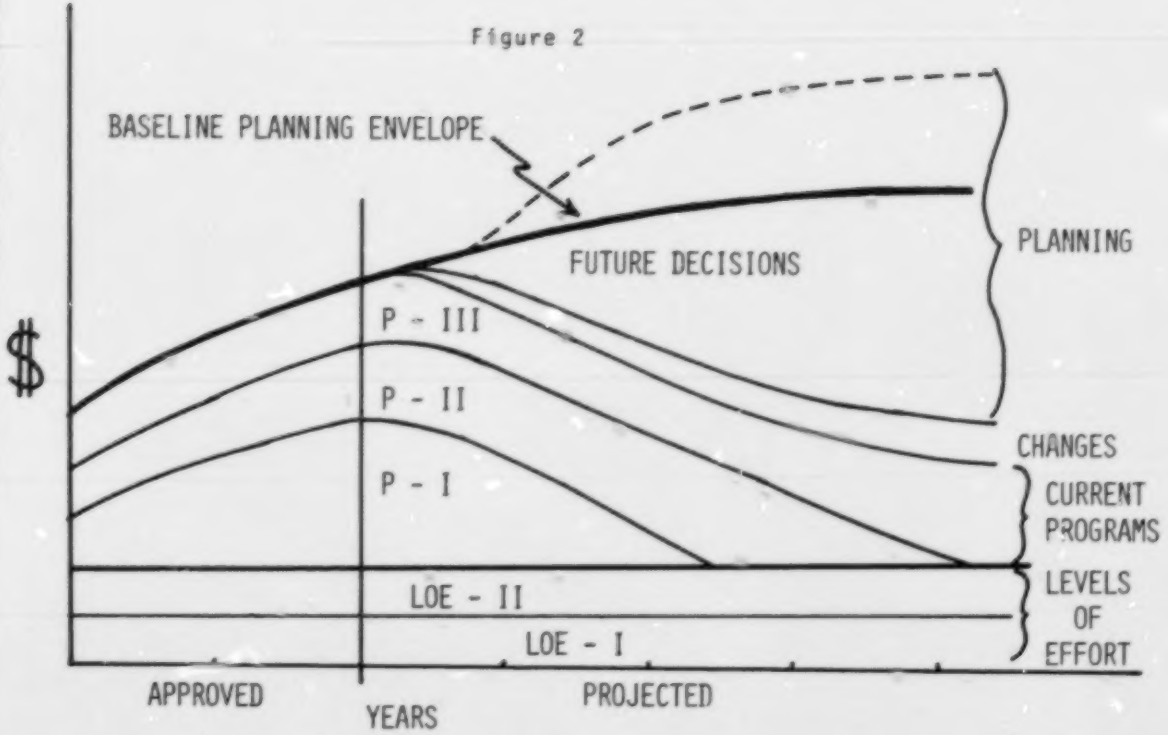
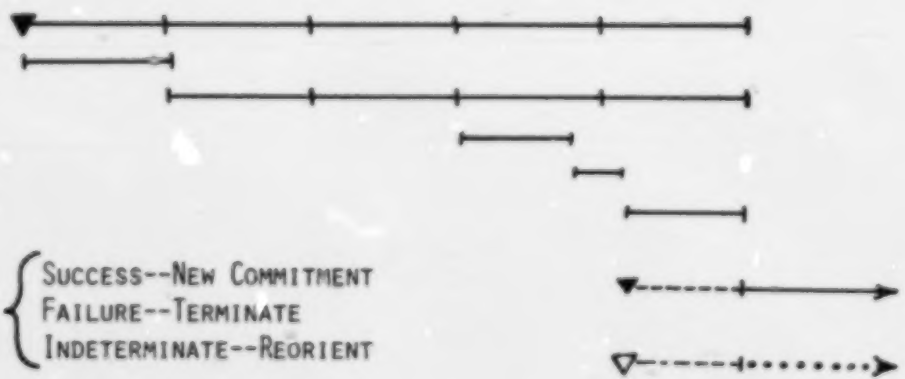

BASELINE PLANNING ENVELOPE
FUTURE DECISIONS
PLANNING
$
P - III
P - II
P - I
CHANGES
CURRENT PROGRAMS
LOE - II
LOE - I
LEVELS OF EFFORT
APPROVED
YEARS
PROJECTED

Figure 3

COMMITMENT-EVALUATION-CYCLE

I. WORK STATEMENT:
   RESULTS, PROGRESS, OR EFFORT INTENDED
   BASIS FOR EVALUATION

II. SCHEDULE:



III. BUDGET

system. The discussion opened with a consideration of the relationship between the federal government's role in supporting R&D and its role in supporting higher education institutions. Mr. Shapley thought that the missing ingredient in the discussion of this issue over the years has been an explicit statement of the federal government's interest, responsibility, and commitment to the support of our higher education system. Currently, we seem to operate according to the guideline that support of research at universities is legitimate but that general support of private universities with federal tax dollars through revenue sharing or other direct means is undesirable both from the standpoint of the government and the institutions. Mr. Cutler stated that the Carter Administration, with major participation by Dr. Frank Press and Dr. Richard Atkinson, is taking a fresh look at this issue. Even if one accepts the notion that we must provide for an adequate capability to conduct basic research, troublesome questions still remain: To what extent should this research be conducted at universities? What other institutions should conduct basic research? Who should fund research at universities? What are the institutional impacts of federal research funds on universities?

Federal R&D decisions also affect R&D decisions made by industry. Responding to Mr. Cutler's presentation in which he stated that the federal government should not be funding "technological winners," a participant felt that industry tends to withdraw from a project when the federal government allocates funds to it. Mr. Cutler generally agreed with this assessment, but warned that there is a problem in determining when along the spectrum from basic research through commercial demonstration the government should cease supporting a project. If the government pulls out too soon, the project may not be picked up by industry. Dr. Calhoun added that some technologies will not be developed without government support, so that the appropriate government involvement depends on the particular technology.

With the exception of new provisions proposed for the FY 1978 NSF authorization bill, no suggestions were made on what the government might do in addition to what it does already to provide incentives for industry to support more basic research. The NSF bill would authorize activities designed to promote greater liaison between those doing basic research with federal support and researchers in industry. It is the hope that closer relationships between these sectors will stimulate additional basic research in industry.

Dr. Davis cautioned the group that the knowledge base about R&D in industry is still very weak, and therefore it is difficult to substantiate many of the allegations that were made. She noted, however, that an improvement in the

information available on industry R&D occurred in 1975 when industry adopted clear definitions, standards, and guidelines for reporting R&D costs on the Form 10-K statements filed with the Securities and Exchange Commission. In fields where we do have an understanding of what industry is doing, for example, cryogenics, aerospace, and electronics, industry is often ahead of the government and universities in the amount of money devoted to basic research and in the results achieved.

There was general agreement that economic, market criteria are inappropriate for decisions on support levels for basic research. Other criteria, based on concerns such as national security, social welfare, and environment, can be used to decide what areas of basic research should be supported, but the problem still remains of establishing criteria to measure the outputs of basic research. Mr. Cooper maintained that we currently do not have the tools to make these measurements, and, in fact, such tools may be impossible to develop.

One participant felt that it was missing the point to consider a rational approach to decision-making on R&D because top-level management does not act rationally. Rather, we should attempt to determine the real bases for R&D decisions by top-level management and the factors that influence people's decisions and opinions. We need to better understand the effects of emotional factors that arise in response to crises, such as Sputnik and the gasoline shortage. Given the complex nature of our society, Mr. Cutler thought we do well with our current tools and resources for decision-making, and would prefer not to pursue the proposition suggested. Mr. Yeager, on the other hand, felt that we should not be content with what we have. Although the capacity may not yet exist within the social sciences to develop these new techniques, this is no reason not to continue trying.

A recurring topic throughout the colloquium was the means by which the scientific community could effectively participate in the R&D budget process. Dr. William McElroy first introduced the subject in this discussion by asking Mr. Yeager how the scientific community could better present the results of research to Congress, to OMB, and to the public. Ideas that first come to mind, such as, compiling the research publications of the last year in a given field or supported by a given agency, highlighting research that is most relevant to the solution of national problems, or tracing the history and emphasizing potential areas for major advances on topics such as DNA and radio-astronomy, do not seem to adequately fulfill the need. Admitting that it was a difficult job, Mr. Yeager did not have any simple answers. He hoped that ways could be found to better package information on the total federal R&D effort to illustrate the progress that has been made. NSF has improved the presentation of information on its programs,

and perhaps OSTP can improve the information available on R&D programs across all agencies. In the view of one participant, Congress needs two kinds of advice: information for long-range issues and timely advice for immediate issues. In-depth reports published by agencies such as GAO, OTA, CRS, and the National Academy of Sciences can fulfill the first need, but other mechanisms must be used for the second. The Congressional Science and Engineering Fellows fulfill all the requirements, but there are not enough to meet the demand. To supplement this resource, experts have been asked to submit written responses to 3-4 key questions on the issue under consideration. The responses have been thorough and timely.

A participant from a federal R&D agency felt that top agency management is often unwilling to listen to descriptions of good basic research. The attitudes of top management toward research need to be changed. Mr. Cooper agreed that there are attitudinal difficulties in the system. If a project has no foreseeable application, managers may rate it low on a list of priorities. In addition, one $200 million applied research and development project often has much more appeal than several $200,000 basic research projects. Mr. Shapley took exception to the characterization of top management presented by the participant. With almost $3 billion currently going to the support of basic research, it is not an area than has been ignored by the decision-makers.

Agriculture was mentioned as an area that was not supporting its share of basic research. For example, research on DNA and on biomass combustion are likely to have important implications for agriculture, yet they have received little or no support from the federal agricultural establishment. As an indication of the desire to improve basic research in agriculture, Mr. Cutler described the current proposal before Congress to establish a competitive grants program in basic research in the Department of Agricuture. The $27 million requested for the first year of the program in FY 1978 was cut by the House, but there is hope that it will fare better in the Senate. Dr. Calhoun referred to the agricultural research system as a good example of what needed to be changed in decision-making on R&D. The system has been too closed, and has not properly evaluated the total scientific system as it relates to agriculture. Any system has a tendency to avoid competition, but the agricultural system should have been exposed earlier to more exchange, analysis, and assessment from a broad point of view rather than remaining largely an internal operation.

Mr. Yeager took an optimistic view of the future of basic research in this country. The pessimism felt by many results from a consideration of trends in the support for basic research over a relatively short period--10 or 20 years. A longer-term perspective might lead to different conclusions.

An assessment made at the end of World War II showed that all the equipment and tools necessary to win the war were developed from basic research conducted outside the U.S. This lesson has not been lost. But, the emphasis on basic research rises and falls. It surged with the concern for atomic energy, and then dropped off. Then, Sputnik stimulated another rise. Industry has not supported more basic research because it has not been forced to. This is becoming evident in the area of energy, and now the energy industry is allocating more funds to energy research and will continue to do so as fossil fuels dwindle. Such a pattern will be repeated as other material shortages occur (for example, food). In order to survive, industry will be forced to obtain new knowledge and thus, we can look for an increase in research supported by industry.

Luncheon Address

Jordan Baruch

Assistant Secretary for
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Jordan Baruch is currently the Assistant Secretary of Commerce for Science and Technology. Prior to coming to Washington, he was Professor of Business Administration and Professor of Engineering at Dartmouth. He had taught previously at the Harvard Graduate School of Business Administration and at MIT. He served as Vice President of Bolt, Beranek and Newman, Inc. and President of Educom, a consortium of 100 colleges and universities.

In addition, Dr. Baruch has served on numerous boards and government advisory panels and committees. He is a member of the National Academy of Engineering and of the American Academy of Arts and Sciences. He received the B.S., M.S., and Sc.D. degrees from MIT.

Dr. Luberoff of Chemical Technology recently sent me an interesting editorial. In it he pointed out that just as some folks grow up thinking Damn Yankee is one word, he's been fighting the population that thinks science and technology is one word. We have similar problems, it seems to me, in research and development. Now few of us here would argue that research and development are the same thing. At best, we tend to think of them as indicial points on some continuum.

For whatever reason, the participants at each end of the continuum often appear to press toward the center, seeming at times to clutch each other like Hansel and Gretal for comfort, at others to join but feud like the characters in "Who's Afraid of Virginia Woolf?" In either case, research and development seems frequently to come out as a single word -- an uncomfortable but solid union. Well, if union it be -- however disparate the partners -- there is some likelihood of progeny. While the liger and the tiglon never caught on, the mule -- that indefatigable offspring of jackass and mare -- played a major role in our country's early development. It subsisted on forage too sparse for a horse but had more intelligence than an ass. It provided much of the underpinning on which our frontier civilization grew.

Now I have no intention of pushing this analogy too far. Indeed, in talking of research and development, I wish I could

have found a successful example of breeding a swan and an eagle, a lion and an elephant, or even better, Captain Marvel and Wonder Woman. At least then I would be painting a better picture of how I really feel about my most valued friends and colleagues.

I believe that the union of research and development is fertile, that the gestation period is over and that the progeny is ready to serve us along with the parents as was the mule. Unlike the mule, hopefully, the offspring will be far from sterile.

There is a class of questions in our society that combines the attributes of the fundamental and the applied. There are, however, few if any institutional structures for dealing with those questions. Despite that shortcoming, however, they are among the most critically important problems relating to our ability to create the goods and services that our society and others demand. They are the questions whose answers are once removed from the actual technological devices that form industry's tools, once removed from the actual systems that provide our services. They are the problems of "infratechnology."

Let me give you an example. The United States apparel industry has troubles. Shirts from Taiwan, Korea and elsewhere pose stiff problems for U.S. industry. The low labor rates of those countries make it nearly impossible for our labor, augmented by the best that our technology has to offer, to compete effectively. We could struggle to get a few more stitches per second or to develop mechanical aids that will help the hand guide the fabric more rapidly. That would be a typical development approach -- relatively incremental additions at the margin of an already established solution. Now it may be time to step back from the machine implementable lockstitch and ask the question whether the inherently linear operation of sewing is an appropriate way to join fabric in a society at our stage of development.

Even sewing, however, is only one step in a series of such steps. We have a sequence of creating fiber, spinning fiber into thread, weaving thread into cloth, cutting cloth into pieces and joining the pieces into our shirts and skirts. It is a sequence that has been little changed from biblical times. It may now be time to ask whether this sequence is an appropriate way in our society to coat, protect and decorate as complex a form as the human body.

We can ask such questions, but who will undertake to answer them? No single company, in the case of the alternative to sewing, can capture the benefits. If company X invested heavily

in a new technology to replace sewing they would be faced with a Hobson's choice. They could try to sell their wares in competition with conventionally made shirts. Their competitors would stress the consumer uncertainties of the new method and make the introduction an uphill battle. If they chose to license widely to avoid that problem, they would (absent illegal agreements) be denied what economists call the monopoly profits that would ordinarily let them recapture their investment and pay for the risk they undertook. Indeed, only under special conditions would even a sewing machine manufacturer undertake such a program -- and a combination of such manufacturers -- particularly if they sell overseas as well -- has neither the incentive nor the legal ability to do it.

In the case of the systemic change -- for example a totally new way of creating and decorating fibers in a three-dimensional shell as a finished garment -- not only do we have that same Hobson's choice facing success, but we don't even have an institutional structure to undertake the project. Chemical companies make fibers, some integrated fabric companies spin and weave designers, cutters and stitchers collaborate on the garment fabrication and they in turn are followed by an entire distribution chain. Who among <u>them</u> is the appropriate agency to tackle the infratechnology of garment forming?

Yet just such developments may be vital to the survival of our textile industry in a world market operating under a growing free trade ethic. In the case of a badly impacted domestic industry like textiles, even labor and management can support such radical technological change. The new capital equipment required will displace the old at a rate set primarily by the profitability of the new process and the capital availability. It won't go unless it is a more advantageous way for management to invest their funds than any other way. Management won't object because they control.

The case of labor is subtler. Salter, a British economist, showed -- over 14 industries -- that, in an industry capable of growth, each 10 percent in productivity led not to layoffs but to a 6 percent <u>increase</u> in employment. Industries impacted by foreign competition are, by their nature, capable of growth. They are called impacted because foreign firms have captured a significant share of the market. The recapture of that market share is -- seen locally -- indistinguishable from growth. Labor in impacted industries is thus unlikely then to impede the action.

Consumers, of course, with their final veto power in the marketplace and as final recipients of the benefits are a major constituency, not a barrier, to any successful outcome.

Note that the creation of either infratechnology is only a precursor to further action. It will be followed by development both of machinery and products. It is bound to be followed by intraindustry transfers. New forms of footcovering, upholstered furniture and even structural members are likely to follow as a natural course. Research activity too, will follow. Gilfillan points out that the invention of the steam engine did more for the science of thermodynamics than thermodynamics did for the invention of the steam engine. Imagine the research in rheology alone that would follow on the creation of a garment-forming infratechnology.

This area of the creation of infratechnology, does, however, face a major barrier. Both of these programs have been started, more than once, and dropped in many companies. They have been started generally by researchers or developers who recognize their potential -- and they have been dropped by managers who recognize the futility if not the hazard of their successful completion. The potential supporters of an infratechnology are too disaggregated to support it effectively; its potential practitioners are scattered among institutions with generally low collaborative potential. It is a classical example of a form of organizational market failure generally ignored by economists. Yet it is just the sort of market failure that prevents Adam Smith's free market from creating major technological innovation. In an economic phrase "major innovations imply major externalities." In certain cases of course, like Alistair Pilkington's development of Float Glass, we had the anomoly of a local monopoly held by a private firm threatened by foreign technological developments; a unique set of countervailing forces provided just what was needed for success. Such unique circumstances, however profitable and instructive, are essentially impossible to institutionalize.

Government, in a mixed economy like ours, tries to institutionalize the conquest of those externalities. In research they have achieved reasonable success by supplying relatively unfettered funds for science. In development, they have been generally successful when they have -- through their purchasing power -- aggregated demand and supported the development specific to that demand. The creation of infratechnology on the other hand has subsisted primarily on the accidental, reluctant or bootlegged outputs of both. The creation of infratechnology is clearly too important at our present stage for us to leave it to chance, charity or chicanery.

Now seems to be a reasonable time for government to nurture the progeny of research and development, to foster the institution building and provide the aggregating support that will lead our nation's creative minds -- whatever their old labels -- to build those new infratechnologies on which a country at our stage of development can build a major aspect of its future.

I suggest that this may be the next creative step in providing national support along the research and development continuum.

Concluding Remarks

William D. Carey
Executive Officer, AAAS

We're now drawing to the conclusion of these two days of colloquium on R&D in the federal budget. What impressions do we carry away with us? For my part, it's a mixture of -- not good and not bad news -- as much as a mixture of light and shadow.

It seems clearer now that on the upside we find a far livelier sense in the higher reaches of the Executive Offices of the strategic role of R&D in the national economy and in influencing productivity. I take this as very encouraging news. A great deal of good can come of it, because it ought to mean that an investment concept can begin to overtake the habit of short-term, opportunity-dominated R&D funding policy. If this is a correct reading of Cutter's and Nordhaus' remarks, it's a new policy signal and a new factor in science policy. I'm encouraged. But it's just a glimmer of light, at this stage, and the next order of business is to debate and develop the policy tools and strategies which can align economic and budget policies to capture the long-term returns of R&D investment. That will take a lot of doing.

It also seems apparent that the base of policy research requires expansion, relative to measures of the vital signs of both industrial R&D performance and university research capacity. In both cases, the indicators are sending out trouble signals and the information base for decision-making is more anecdotal than systematic. That information base needs attention, and quickly, before the problems reach crises stages. And that, too, will take a lot of doing.

I think we have sensed something else -- that R&D funding policies have not yet begun to provide answers to the problem of industry *cum* government collaboration in R&D where the public interest is very acutely concerned, as in the field of energy supply. Here we have institutional problems that are not being faced, and where large federal R&D outlays alone are not going to do the job. Exposing these hangups and devising new arrangements is an obvious priority for policy research.

I think it became very clear that basic research has won some powerful friends in high places. But that good news is balanced by well-founded concerns for the development of a rational substitute for criteria of economic utility which can be effective in the coming contest of priority tradeoffs within the

Zero-Base Budgeting system. I heard nothing that causes me to expect basic research support to shrink, but I heard enough to persuade me that in the absence of more effective justification, basic research won't grow relative to applied research and development, and will probably stay only a couple of points ahead of the rate of inflation.

I was encouraged by the signs of Congressional interest and performance in dealing with budgetary choices involving R&D. The Congress has come a long way in a short while, and its institutional tools for scientific and technical input are impressive. There is an appetite there for a better relationship with the scientific and technical sectors, and what I heard makes me believe that what's missing is a delivery system, and I believe we should pick up that challenge.

We took on the question of whether there are better ways to approach R&D budgeting, and I think we came closer to some useful propositions. What I'd like to see next is a joint examination of those ideas by OMB, OSTP, and the AAAS, and we'll see if we can work that out. But perfectability isn't attainable. We will make progress a bite at a time, with good will and good faith -- and we've seen evidence of both.

Last year we tackled the large problem of R&D and the federal budget on a shoestring, with no real idea as to how it would turn out. Now we have two special reports and two extremely lively colloquia behind us. My sense of the situation is that we can't stop now. We have to go on and keep trying for higher ground. Our debt to Willis Shapley, and to the Sloan Foundation, and our Committee on Science and Public Policy is very large. I think that AAAS has begun to get an effective handle on ways to make a difference in science policy, and I wish I could tell you what it does for me to see government, industry, universities, and public interest groups converging on these questions.

What should be the focus of a third report and a third colloquium? One possibility is to focus on R&D in the national economy, meaning not just federal government R&D support but industrial, university, and state government support. But I want to hear from you on this matter, with your ideas and preferences, and I hope you'll send me your thoughts.

To all the panelists, distinguished speakers, colloquium participants, and AAAS colleagues, my grateful thanks.

We are adjourned.

Appendix

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